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Attachment to

D-30 BY-PASS TURBOJET ENGINE

Description

(TU-134)

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Д-30 BY-PASS TURBOJET ENGINE

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DESCRIPTION

Part I

GENERAL DATA

Chapter I

GENERAL DATA

1. GENERAL INFORMATION

The Д-30 engine (Figs 1 and 2) is a by-pass, two-shaft turbojet engine possessing a two-spool compressor. As compared to other types of aircraft turbojets, the by-pass (two air flow ducts) configuration ensures high fuel economy at any flight conditions, simple operation, low noise level, cold exterior shrouds of the engine. The engine high performance data are attained due to a higher air flow, turbine inlet temperature, compressor pressure ratio, high efficiencies of the engine components, low hydraulic losses in the engine flow path and due to efficient mixing of the by-pass duct air flow and of the main duct gas flow.

The Д-30 by-pass turbojet is designed for high-speed medium-range passenger airliner Ту-134. The two-shaft turbojet employs a two-spool compressor and two air-flow ducts (by-pass and main).

A two-stage (first) high-pressure turbine drives the compressor high-pressure rotor, which delivers air into the main air duct, whereas a two-stage (second) low-pressure turbine imparts rotation to the compressor low-pressure rotor, feeding compressed air both into the by-pass and main ducts of the engine.

The two-shaft configuration materially improves engine performance, provides for more easy starting and allows faster acceleration of the engine within the ambient air temperature range from plus 50°C to minus 50°C. The engine is controlled by means of a single lever.

To allow operation of the engine under any weather and climatic conditions, use has been made of appropriate materials and reliable anti-corrosion coatings in the engine construction. The engine has a low weight-to-thrust ratio which is a result of wide use of titanium and aluminium alloys and profound development of the engine units and parts.

To ensure safe flying of the aircraft, the engine is provided with automatic de-icing means, internal and external fire-fighting systems, chip-detecting system, vibration measuring equipment and jet pipe temperature limiting system.

The Д-30 engine consists of the following main units and systems:

(a) an axial, four-stage low-pressure compressor section;

(b) a by-pass duct entry housing carrying drive gear boxes;

(c) an axial, ten-stage high-pressure compressor section;

(d) a cannular combustion chamber enclosing twelve flame tubes;
(e) a two-stage (first) gas turbine;
(f) a two-stage (second) gas turbine;
(g) main and by-pass flow mixing jet nozzle;
(h) an engine fuel supply and automatic control system;
(i) a lubricating oil and breathing system;
(j) a power supply and starting system;
(k) a fire-fighting system;
(l) external fittings and components serving for engine mounting on the aircraft.

2. PRINCIPLE OF OPERATION AND ENGINE KINEMATICS

The air drawn in by the low-pressure section of the compressor flows in the axial direction, gets compressed in the compressor low-pressure section and is carried into the by-pass duct entry housing. Here, the air is divided into two streams flowing into the by-pass and main engine ducts. The air flowing through the by-pass duct enters the mixing jet nozzle.

The air flowing through the main duct of the engine enters the high-pressure section of the compressor, where it is additionally compressed to be directed into the combustion chamber. In the combustion chamber the air is heated at the expense of continuously burning fuel which is delivered into the flame tubes via burners ФР-30ДС. Part of the air in the combustion chamber sustains burning of fuel, whereas the main portion of the air mixes with hot gases, thereby reducing the temperature of the gases so as to ensure more favourable conditions for the operation of the combustion chamber components and the turbine. A stream of hot gases leaving the combustion chamber causes rotation of the two-stage (first) and two-stage (second) turbines, then enters the mixing jet nozzle to get mixed with the by-pass duct air and discharged into the atmosphere at great velocity.

Thus, the total engine thrust is composed of the thrusts built up in the by-pass and main engine ducts.

Power developed by the first turbine is consumed in driving the compressor high-pressure rotor and all the accessory units, excluding centrifugal speed governor ЦР-1Б and compressor low-pressure rotor tachometer generator ДТЭ-5Т.

Power developed by the second turbine is consumed in driving the compressor low-pressure rotor, centrifugal governor ЦР-1Б and compressor low-pressure rotor tachometer generator ДТЭ-5Т.

The engine kinematics (Fig.5) consist of two individual systems:

(a) the compressor low-pressure section - the second turbine;
(b) the compressor high-pressure section - the first turbine.

The compressor low-pressure rotor is driven by the second turbine through the medium of an intermediate splined shaft. The compressor low-pressure rotor rides in two bearings: the front roller beari g and the rear radial-thrust ball bearing.

The front roller bearing and the shaft of the second turbine are enclosed in the compressor high-pressure rotor shaft and the first turbine shaft respectively. The rearmost second turbine rotor support comprising a roller bearing is constructed integral with the mixing jet nozzle assembly.

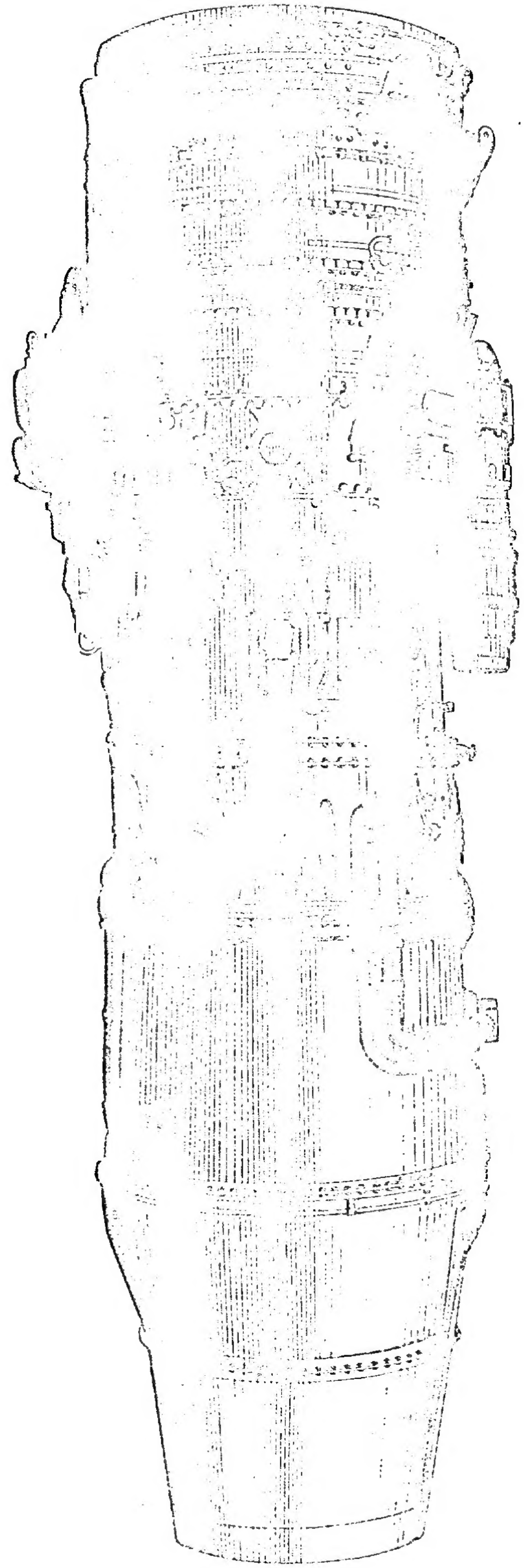

FIG. 1. [illegible] ENGINE
(left-hand view)

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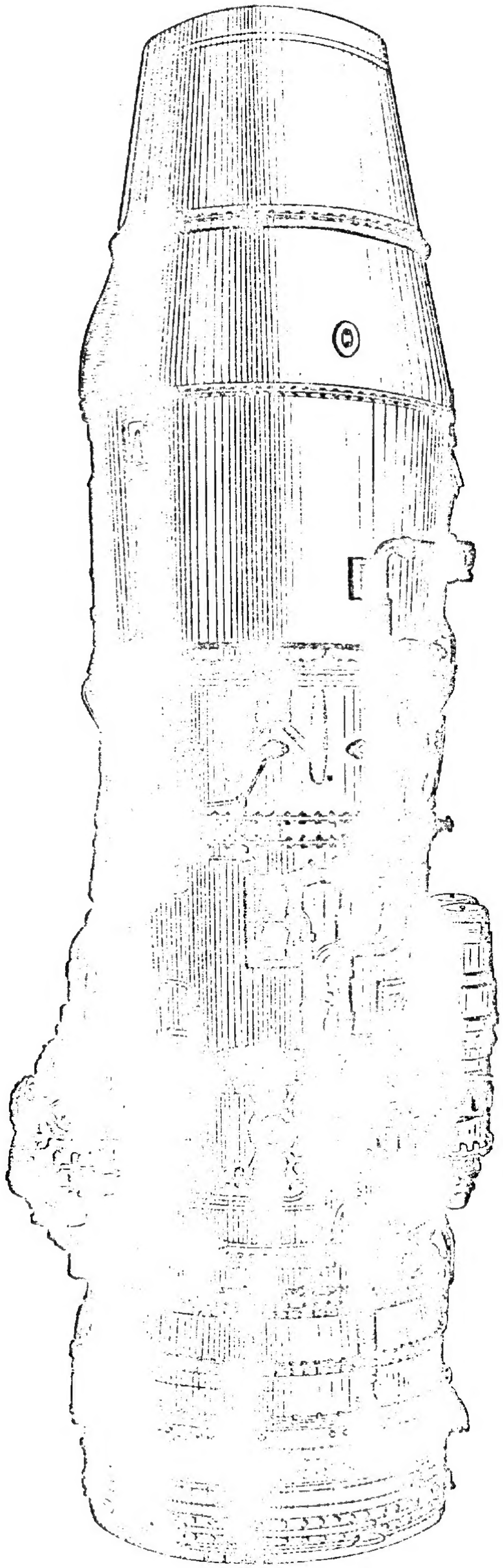

FIG. 2. Л-30 ENGINE
(right-hand view)

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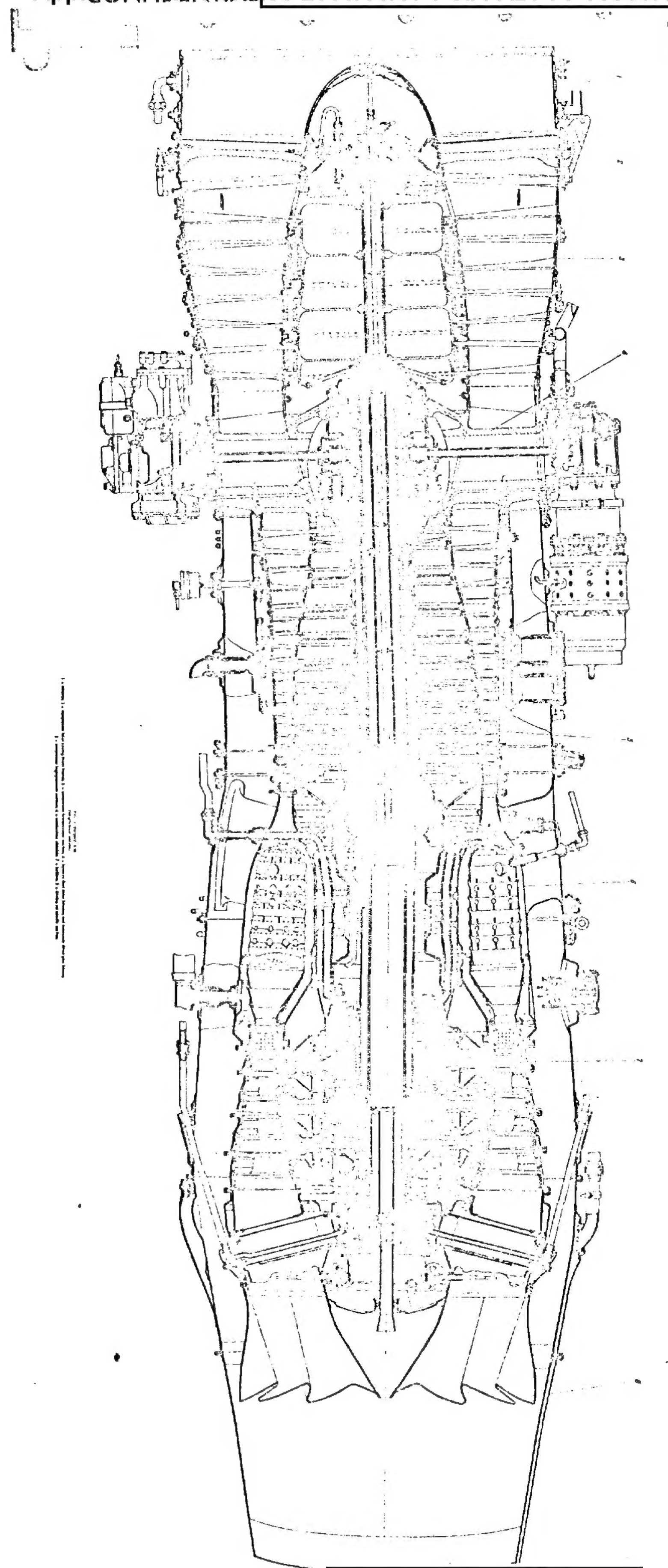

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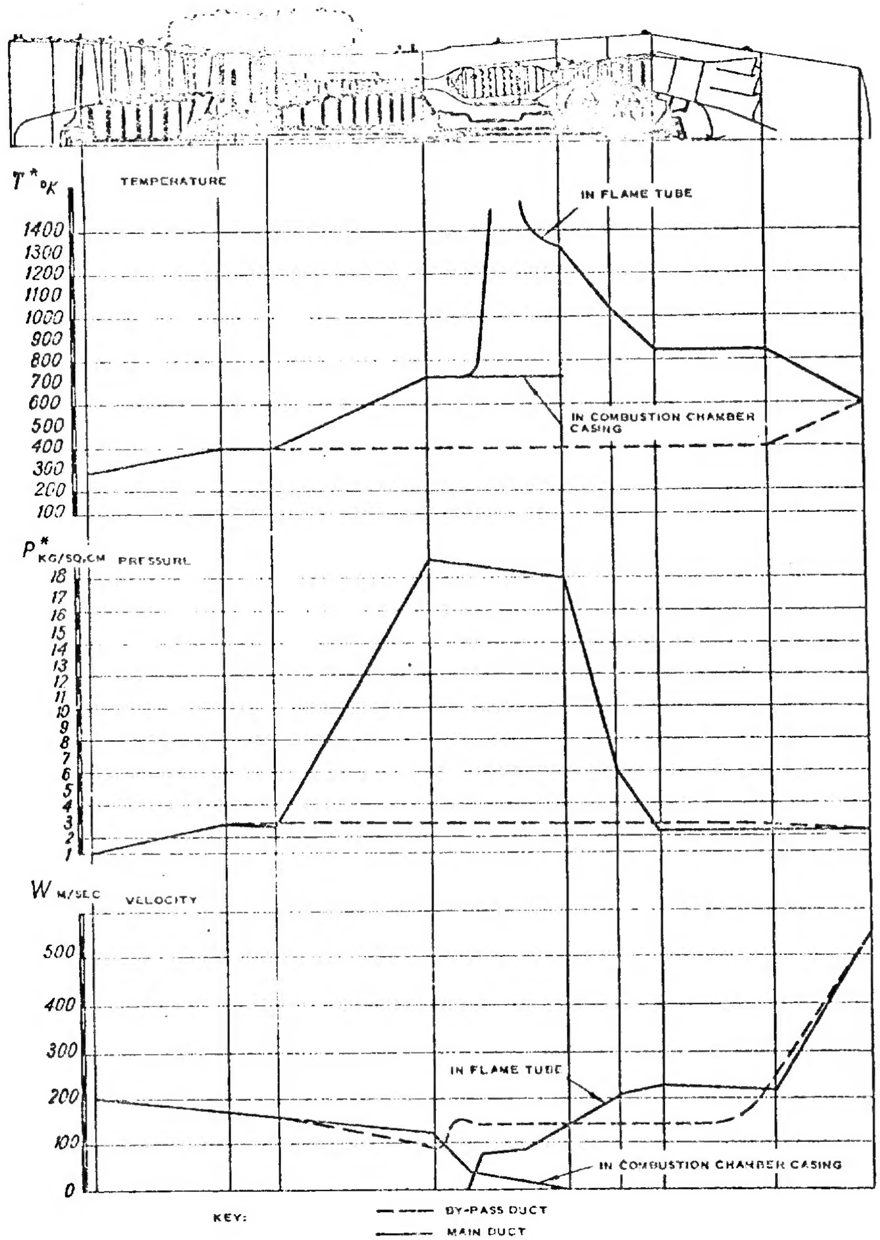

FIG. 4. VARIATION OF ENGINE PARAMETERS ALONG AIR AND GAS FLOW PATHS

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The compressor high-pressure rotor is driven by the first turbine, the compressor and first turbine shafts being coupled by means of a splined joint and a coupling sleeve. The compressor high-pressure rotor runs in two bearings: the front roller bearing and the rear radial-thrust ball bearing which serves at the same time as a front support for the first turbine shaft. A roller bearing acts as a rear support for the first turbine shaft.

The drives accommodated in the upper gear box are actuated by the compressor high-pressure rotor shaft through the medium of a spur gear mounted on compressor shaft splines, driving and driven bevel gears and an upper vertical shaft. The upper gear box accommodates the drives of the following accessory units:

I - centrifugal breather МС-30,
II - high-pressure rotor tachometer generator ДТЭ-5Т,
III - СТГ-12ТМО starter-generator (two drives).

The drives arranged in the right-hand drive gear box are driven by the compressor low-pressure rotor shaft through the medium of a spur gear splined onto the l.p. rotor shaft, a pair of bevel gears and a splined shaft.

The right-hand drive gear box accommodates the drives of the following accessories:

XII - centrifugal speed governor ЦР-1Б of compressor l.p. rotor,
XIII - low-pressure rotor tachometer generator ДТЭ-5Т.

The drives located in the lower drive gear box are driven by the shaft of the compressor high-pressure rotor. Accommodated in the lower drive gear box are the drives of the following accessory units:

IV - hydraulic pump НП43-1 or НП43М-1;
V - ОМН-30 main oil pump;
VI - МНО-30 oil scavenging pump;
VII - НР-30 fuel regulating pump;
VIII - ЦР-2Б centrifugal speed governor of h.p. rotor;
IX - ЦВО-СС-30 centrifugal deaerator;
X - ДЦН-44-П3Т fuel booster pump;
XI - stand-by drive.

When the engine is being started, the torque is transmitted from the two starter-generators to the compressor high-pressure rotor via the bevel gears and the vertical splined shaft of the upper drive gear box.

3. MAIN TECHNICAL DATA

General

1. Engine model designation Д-30
2. Engine type .... turbojet, by-pass, two-shaft
3. Direction of rotation of compressor and turbine rotors (looking from exhaust unit end) .... counter-clockwise
4. Compressor:
   - type .... axial, two-spool
   - number of stages:
     (a) low-pressure section 4
     (b) high-pressure section 10

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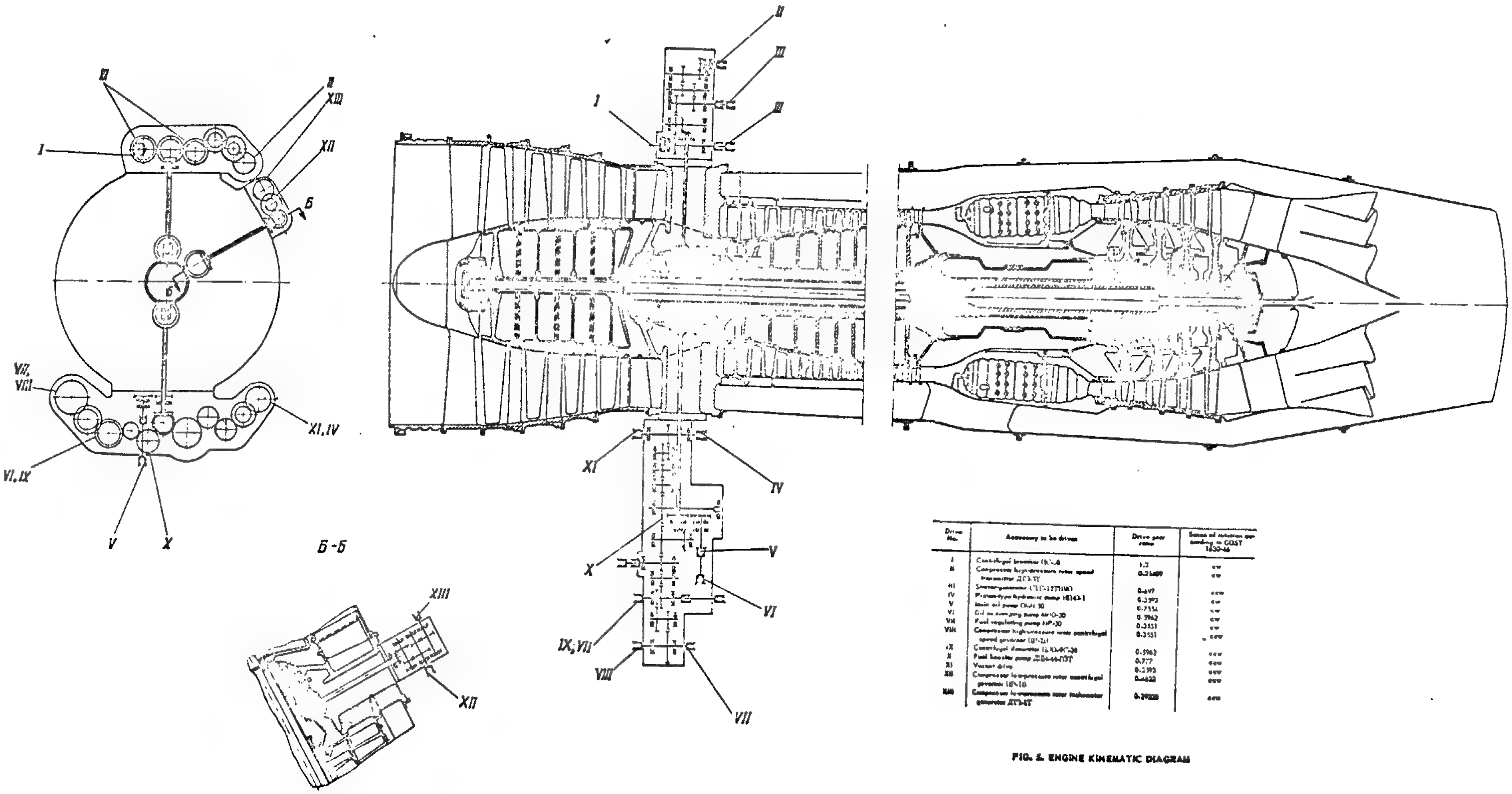

Drive No.	Accessory to be driven	Drive gear ratio	Sense of rotation according to GOST 1630-46
I	Centrifugal breather ЦС-8	1.3	cw
II	Compressor high-pressure rotor speed transmitter ДТЭ-5Т	0.21409	cw
III	Starter-generator СТГ-12ТМО	0.697	ccw
IV	Piston-type hydraulic pump НП43-1	0.3593	cw
V	Main oil pump ОНМ-30	0.7354	cw
VI	Oil scavenging pump ОНО-30	0.5962	cw
VII	Fuel regulating pump НР-30	0.3551	cw
VIII	Compressor high-pressure rotor centrifugal speed governor ЦР-2	0.3551	ccw
IX	Centrifugal deaerator ЦБ-30	0.5962	ccw
X	Fuel booster pump ДЦН-44-ПТ	0.777	ccw
XI	Vacuum drive	0.2593	ccw
XII	Compressor low-pressure rotor centrifugal governor ЦР-1Б	0.4632	ccw
XIII	Compressor low-pressure rotor tachometer generator ДТЭ-5Т	0.29228	ccw

FIG. 2. ENGINE KINEMATIC DIAGRAM

- pressure ratio under standard atmospheric conditions on ground (H = 0, V = 0):

	Engine rating: take-off	Engine rating: normal
(a) low-pressure section	2.65±0.1	2.3±0.1
(b) high-pressure section	7.1±0.1	6.4±0.1
(c) total pressure ratio	18.4±0.2	14.5±0.2

5. Combustion chamber:
   - type .... cannular
   - number of flame tubes 12
   - arrangement of flame tubes .... along circumference relative to engine axis
   - flame tube numbering .... counter-clockwise (looking from exhaust unit end); upper left-hand flame tube (relative to engine vertical axis) being flame tube No.1
6. Turbine:
   - type .... axial
   - number of stages:
     (a) first turbine 2
     (b) second turbine 2
7. Jet nozzle:
   - type .... mixing, subsonic, fixed-area
   - mixing jet nozzle exit area, sq.m. .... 0.34±0.001

<u>Lubricating Oil System</u>

1. Lubricating system .... open-circuit, with scavenging oil into tank
2. Oil grades .... МК-8 (State Standard GOST 6457-53), МК-8П (Specification МРТУ12Н No.12-62), with viscosity amounting to not less than 8 centistokes at 50°C; ВНИИ НП50-1-4ф (Specification МРТУ-38-1-164-65) with viscosity amounting to not less than 3.2 centistokes at 100°C.

<u>Notes</u>: 1. It is allowed to use a mixture of oil МК-8 and oil МК-8П in any proportion.
2. Refer to Table on Page 66 to replace oil grades produced in the USSR by foreign oil products for use in the engine.

3. Oil consumption, kg/hr:
   - on the ground .... not over 1.5
   - in flight .... not over 1.0
4. Oil pressure at engine inlet, kg/sq.cm:
   - with engine operating at idling rating ......2.5, min
   - with engine operating at other ratings ......3.5 - 4.5
   - when adjusting engine at 0.7 normal rating ..4 ± 0.2

5. Oil temperature at engine inlet, °C:
   - recommended .... 50 - 70
   - maximum permissible 80
   - minimum:
     (a) when operating on oil grades МК-8 and МК-8П .... - 30
     (b) when operating on oil grade ВНИИ НП50-1-4Ф .... - 40
   - maximum permissible for not more than 10 min 90

   <u>Note</u>: After the engine comes to a standstill, engine inlet oil temperature may rise to 95°C.

6. Maximum permissible oil temperature at engine outlet, °C 120
7. Rate of oil flow through engine at normal rating, with inlet oil temperature amounting to 80°C, kg/min .... 27 - 36
8. Heat transfer to oil at normal rating, with inlet oil temperature equal 80°C, Cal/min .... not over 525
9. Main oil pump:
   - designation ОМН-30
   - type .... gear-type, two-element, including delivery and scavenging elements
   - number 1
   - delivery section output, at normal rating with counter-pressure of 4 kg/sq.cm, and pressure control valve plugged, lit/min .... not less than 120
   - scavenging section output at normal rating, with counter-pressure amounting to 1 - 1.5 kg/sq.cm, lit/min .... not less than 100
10. Oil scavenging pump:
   - designation МНО-30
   - type .... gear-type, comprising four scavenging elements
   - number 1
   - pump output at normal rating, with counter-pressure amounting to 1 - 1.5 kg/sq.cm (total output of four elements), lit/min ... not less than 175
11. Centrifugal deaerator, provided with chip-detecting filter:
   - designation ЦВО-ЗС-30
   - number 1
12. Centrifugal breather:
   - designation ЦС-30
   - number 1
13. Main oil filter:
   - designation МФС-30
   - type .... gauze
   - number 1

[redacted]

5. Oil temperature at engine inlet, °C:
   - recommended .... 50 – 70
   - maximum permissible 80
   - minimum:
     (a) when operating on oil grades МК-8 and МК-8П .... – 30
     (b) when operating on oil grade ВНИИ НП50-1-4Ф .... – 40
   - maximum permissible for not more than 10 min 90

   Note: After the engine comes to a standstill, engine inlet oil temperature may rise to 95°C.

6. Maximum permissible oil temperature at engine outlet, °C 120
7. Rate of oil flow through engine at normal rating, with inlet oil temperature amounting to 80°C, kg/min .... 27 – 36
8. Heat transfer to oil at normal rating, with inlet oil temperature equal 80°C, Cal/min .... not over 525
9. Main oil pump:
   - designation ОМН-30
   - type .... gear-type, two-element, including delivery and scavenging elements
   - number 1
   - delivery section output, at normal rating with counter-pressure of 4 kg/sq.cm, and pressure control valve plugged, lit/min .... not less than 120
   - scavenging section output at normal rating, with counter-pressure amounting to 1 – 1.5 kg/sq.cm, lit/min .... not less than 100
10. Oil scavenging pump:
   - designation МНО-30
   - type .... gear-type, comprising four scavenging elements
   - number 1
   - pump output at normal rating, with counter-pressure amounting to 1 – 1.5 kg/sq.cm (total output of four elements), lit/min ... not less than 175
11. Centrifugal deaerator, provided with chip-detecting filter:
   - designation ЦВО-6С-30
   - number 1
12. Centrifugal breather:
   - designation ЦС-30
   - number 1
13. Main oil filter:
   - designation МФС-30
   - type .... gauze
   - number 1

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Fuel system

1. Grade of fuel (main and starting), kerosene .. T-1, TC-1 (State Standard GOST 10227-62), TC-1Г (according to Specification МРТУ 12Н No.36-63)

   Notes: 1. When operating the engine on the above fuel grades at subzero ambient air temperatures do not fail to use additives preventing ice-needle formation in fuel.
   2. The engine may operate on fuels T-1, TC-1 and TC-1Г mixed in any proportion.
   3. Refer to Table on Page 66 to replace fuel grades produced in the USSR by foreign fuel products for use in the engine.

   - fuel temperature during engine operation, °C .... -50 to +80
   - maximum permissible temperature of fuel for not more than 10 min of continuous operation, °C 90

2. Fuel booster pump:
   - designation ДЦН-44-П3Т
   - type .... centrifugal
   - number 1
   - fuel pressure (absolute) at pump inlet, kg/sq.cm
     (a) during starting on the ground .... 1.7 - 2.7
     (b) during operation at any rating .... 0.3 - 2.5

3. Fuel burners:
   - designation ФР-30ДО
   - type .... centrifugal, two-duct, two-nozzle
   - number 12
   - fuel pressure in primary manifold, at which main fuel manifold starts functioning, kg/sq.cm .... 14, min
   - maximum fuel pressure in primary manifold upstream of burners, kg/sq.cm 65

Automatic Fuel Control System

1. Fuel regulating pump:
   - designation НР-30
   - type .... plunger type, with centrifugal speed governor
   - number 1
   - fuel starts to be supplied into the engine automatically as soon as compressor high-pressure rotor gains speed of, rpm .... 9700 ± 50 (82.5 - 83.5%)
   - engine speed limited by over-temperature control system ИРТ-35, rpm .... 10500 ± 75 (89.5 - 90.5%)
   - acceleration time from idle speed to rpm value by 180 rpm less than take-off rating rpm, and to 95 per cent take-off thrust, sec .... 10 - 15

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- exhaust-gas temperature during acceleration check (measured as average by means of 12 thermocouples), °C .... 620, max
- fuel pressure at fuel regulating pump inlet, kg/sq.cm .... 1.8 - 2.9

2. Centrifugal speed governor designed for limiting maximum rpm of compressor low-pressure rotor:
   - designation HP-1B
   - type .... hydromechanical
   - number 1
   - limiting speed of compressor low-pressure rotor, rpm .... 7900^{+50}_{-25} (92.5- 93.5%)

3. Centrifugal governor, designed for automatic control of compressor high-pressure rotor speed:
   - designation HP-2B
   - type .... hydromechanical
   - number 1
   - speed at which voltage supply is cut off starter-generators (operating as starters) and at which ice warning system is energized, rpm .... 4500 ± 200 (37 - 40%)
   - speed at which air blow-off shutters aft of 4th and 5th stages of compressor h.p. rotor get closed and IGV position angle is changed over from -10 deg. to 0 deg., with rotor speed increasing, rpm .... 9400^{+125}_{-175} (79 - 81.5%)
   - speed at which aircraft air intake de-icing air supply is changed over from 10th to 5th stage of compressor high-pressure section, with rotor speed increasing, rpm .... 9400^{+125}_{-175} (79 - 81.5%)
   - speed at which de-icing air butterfly valves are changed over from bleeding air aft of compressor h.p. section 5th stage to bleeding air aft of compressor h.p. section 10th stage and at which IGV position angle is changed over from 0 deg. to -10 deg., with rotor speed decreasing, rpm. .... 9100 ± 100 (77 - 79%)

4. Actuators controlling air blow-off shutters aft of 4th and 5th stages of compressor high-pressure section, butterfly valves for bleeding de-icing air either from 5th or 10th stage to supply it to aircraft air intake and low-pressure compressor section IGVs, as well as turning variable IGVs of compressor high-pressure section:
   - type .... hydraulic

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- number 6
- maximum fuel pressure in hydraulic actuators, kg/sq.cm 60

Starting System

1. Voltage supply and starting system:
   - designation СП3-30
   - type .... self-contained, electric
2. Starter-generator used as starter during engine starting, and as D.C. generator during engine operation:
   - designation СТГ-12ТМО
   - number 2
   - drive gear ratio:
     (a) at starter duty 2.208
     (b) at generator duty 0.697
   - direction of rotation .... counter-clockwise
3. Automatic starting control unit:
   - designation .... АПД-19БЛ, series II
   - number (per two engines) 1
   - time of operation at starter duty, sec:
     (a) during engine cranking .... 30 - 36
     (b) during engine starting .... 45 - 50
4. Voltage regulator:
   - designation .... РН-180, series II
   - number 2
5. Reverse current cut-out relay:
   - designation .... ДМР-400Т, series II
   - number 2
6. Starting control panel:
   - designation .... ПСГ-2А, series II
   - number (per two engines) 1
7. Starter-generator overvoltage automatic circuit breaker:
   - designation .... АЗП-8М, series IV
   - number 2
8. Relay:
   - designation РКС-1
   - number (per two engines) 1
9. Ignition system:
   - ignition unit designation СКНА-22-2А
   - type .... low-voltage, with capacitance discharge
   - number 1
   - time of operation, sec:
     (a) during ground starting 45
     (b) in flight starting 60

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10. Ignition plugs:
   - designation СП-06ВП
   - type .... surface discharge
   - number 2

   Note: Accessory units listed under Items 3, 4, 5, 6, 7, 8 are installed at the aircraft Manufacturing plant.

11. Number of starting cycles performed from three storage batteries 12САМ-55 without boost-charging ... 3
12. Time required by engine for gaining idle speed on ground, after pressing START button, sec .... 120, max.
13. Number of starts within service life .... according to the Service Log of the engine
14. Exhaust gas temperature at starting, °C .... 620, max.
15. Critical altitude for engine starting, km 7

Electrical Equipment
(installed at aircraft Manufacturing plant)

1. Compressor high-pressure rotor tachometer:
   (a) tachometer generator:
      - designation ДТЭ-5Т
      - number 1
   (b) tachometer indicator:
      - designation ИТЭ-2Т
      - number (per two engines) 1
2. Compressor low-pressure rotor tachometer:
   (a) tachometer generator:
      - designation ДТЭ-5Т
      - number 1
   (b) tachometer indicator:
      - designation ИТЭ-2Т
      - number (per two engines) 1

   Notes: 1. Compressor low-pressure rotor speed is not an engine parameter to be measured regularly. Therefore, an additional panel must be provided in the aircraft for installation of the tachometer indicator in case of need.
   2. It is allowed to employ tachometer generators ДТЭ-1 and tachometer indicators ИТЭ-2.

3. Electric rotor indicator intended for measuring fuel pressure in burners, inlet oil temperature and pressure:
      - designation ЭМИ-3РТИ
      - number .... 1 set
   (a) engine inlet oil temperature transmitter:
      - designation П-63
   (b) engine inlet oil pressure transmitter:
      - designation .... ИДТ-8, series III (with snubber Д59-4)
   (c) primary manifold fuel pressure gauge transmitter:
      - designation .... ИДТ-100, series III (with snubber Д-59-2)

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(d) indicator:
- designation .... УИ3-3, series II

4. Standard remote-reading fuel regulating pump inlet pressure gauge of induction type:
- designation .... ДИМ-4Т, series III
- number .... 1 set

(a) transmitter designation .... ИДТ-4, series III (with snubber Д59-4)

(b) indicator designation .... УИ1-4, series II

5. IGV position microswitch (installed on engines):
- designation A-812K
- number 1
- with IGVs at 0 deg. position .... light is out
- with IGVs at -10 deg. position .... light is on

Air Bleed System

1. Air bleed for passenger cabin pressurization:
- compressor high-pressure section stage after which air is bled 8
- number of air bleed flanges .... 1 (right or left)
- amount of air tapped at rating equal to 0.88 normal rating, kg/hr:
  (a) at H = 6000 m and V = 600 km/hr 2000
  (b) at H = 11,000 m and V = 700 km/hr 1800

2. Air bleed for aircraft wing and fin de-icing systems:
- stage of compressor high-pressure section after which air is bled 5
- number of air bleed flanges 1
- amount of air bled at 0.88 normal rating, kg/hr:
  (a) at H = 0 and V = 400 km/hr 5200
  (b) at H = 6000 m and V = 500 km/hr 3100

3. Air bleed for aircraft air intake de-icing system:
- compressor high-pressure section stage after which air is bled at speed of up to 9400^{+125}_{-175} rpm (79 - 81.5%) 10
- compressor high-pressure section stage after which air is bled at speeds from 9400^{+125}_{-175} rpm to maximum take-off rating 5
- air bleed system control .... automatic
- number of air bleed flanges 1
- amount of air bled aft of 10th stage at idling rating, kg/hr:
  (a) at H = 0 and V = 400 km/hr 1100
  (b) at H = 6000 m and V = 500 km/hr 1050
- amount of air bled aft of 5th stage at 0.88 normal rating, kg/hr:
  (a) at H = 0 and V = 400 km/hr 1500

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(b) at H = 6000 m and V = 500 km/hr 720

4. Air bleed for aircraft hydraulic tank pressurization system:
- stage of compressor high-pressure section after which air is bled 10
- number of air bleed flanges 1

Notes: 1. Air bleed for pressurization of the passenger cabin is performed at all the flight altitudes and any engine rating up to rpm value not exceeding 95%.
2. Anti-icing air for the aircraft wing, fin, and intake de-icing systems may be bled at flight altitudes up to 10.000 m and to engine rpm not exceeding 95%.
3. At take-off rating compressed air may be bled only for aircraft air intake and engine de-icing systems at flight altitudes up to 2000 m. With the air bleed systems of the aircraft air intake and engine de-icing systems cut in, the engine runs at maximum take-off rating under control of overtemperature controller ИРТ-35 adjusted to temperature limit exceeding by 15°C the rated exhaust gas temperature at maximum take-off-rating with no air bled to other aircraft needs. The engine must not operate longer than 2 min at maximum take-off rating with the de-icing air bleed system cut in.
4. Air for pressurization of the aircraft hydraulic tank is bled at all operating conditions of the engine.
5. Air bleed for feeding the freon plant is allowed with the air intake de-icing system inoperative, at any rating up to rpm not exceeding 95%.
6. Amounts of air bled are given for standard atmospheric conditions.

Turbine Outlet Gas Overtemperature Control System ИРТ-35

(a) Overtemperature controller amplifier (installed on aircraft, supplied with engine):
- designation УРТ-19А-2Т
- number 1
- operating voltage across amplifier terminals, V .... 27 ± 10%
- temperature limit surplus as compared to take-off rating JPT, at standard atmospheric conditions, °C .... +15

(b) Twin thermocouples (supplied with engine):
- designation Т-99-1
- number 12

(c) Overtemperature limiter actuating unit provided with solenoid ЭМТ-243 (mounted on fuel regulating pump НР-30):
- designation .... ОТ
- number 1

(d) Jet pipe temperature gauge:
- designation ИТ-2Т
- number 1

Note: It is permissible to employ JPT gauges, model ИТ-2.

Vibration Measuring Equipment
(installed at the aircraft Manufacturing plant)

- designation ИВ-200Е
- number (per two engines) .... 1 set

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(a) electronic unit:
- designation B2-6
- number 1

(b) vibration pick-up:
- designation MB-25E-B
- number 2

(c) indicator:
- designation M-53C
- number 2

Note: The electronic unit is fed from A.C. mains with 115 V ± 5%, 400 cps current.

De-Icing System

- type .... thermopneumatic (nose bullet and compressor l.p. section IGVs are heated by air bled from compressor h.p. section aft of 5th or 10th stages)

Engine nose bullet and IGV de-icing warning system units (supplied with engine):

(a) ice detector:
- designation ДО-202М
- type .... electropneumatic with ejector
- feed voltage, V .... 27 ± 10%
- number 1

(b) solenoid-operated valve:
- designation M782000
- number 1

(c) pressure switch, standard:
- designation СДУ2-0.15
- number 1

(d) butterfly valve electric actuator:
- designation МП-5Н
- number 1

Fire-Fighting System

- designation of engine fire alarm system 2С7К
- type .... thermoelectric
- number (per two engines) .... 1 set

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(a) fire detector:
- designation ДП-6
- number 2
- temperature at which signal is sent, °C .... 550^{+150}

(b) amount of fire extinguishant (freon 114B-2) used for fighting fire inside engine, kg 2.725

Note: Fire detectors ДП-6 are supplied together with the engine.

Engine dry weight, kg .... 1550 ± 2%

Note: The dry weight of the engine does not include the weights of the following parts:
- front frame adaptor – 15 kg,
- upper drive gear box – 33 6 kg,
- two starter-generators СТГ-12ТМО – 74 kg,
- piston pump НП43-1 – 9.6 kg,
- engine sling brackets – 8.9 kg,
- checking and measuring instruments: ИЭ-51 (2 pcs), ДИ-5 (2 pcs), П-63, ИЭ-9 (series III), ИТ-100 (series III), ИЭ-4 (series III), ИВ-25В-2 – 4, 6 kg,
- parts and units of air bleed system for aircraft needs – 9.5 kg,
- fire-fighting system component parts – 6 kg,

Engine overall dimensions, mm:
- length .... 3983.5 ± 10
- diameter (across compressor l.p. section front frame outline less protruding ducts and brackets) 1050

C.G. position as measured ahead of plane of engine attachment unit on load-carrying ring (for engine furnished with set of all accessory units, aircraft accessories included), mm .... 40 ± 10

Engine service life before first overhaul .... recorded in Service Log

- including engine operating time:
  - at maximum take-off rating 5%
  - at normal rating 40%
  - at other ratings .... not restricted

Note: Engine accumulated hours in service are summed up of engine operating time in flight and 20 per cent of engine running time on the ground.

Maximum permissible engine vibration overloads, as measured from side attachment unit sides:
- of attachment unit load-carrying hanger housing .... 3.5 g
- of compressor IGV assembly .... 3.5 g
- of by-pass duct entry housing .... 4 g

Aircraft Accessory Units Mounted on Engine

1. Starter-generator СТГ-12ТМО (supplied with engine) .... see Item 2 under "Starting System" in this Chapter

2. Piston pump (not supplied with engine)

[redacted]

- designation .... НП43-I or НП43М-I
- type .... plunger
- number I

3. Vacant (stand-by) drive (employed for cranking compressor h.p. rotor):
- number I
- permissible output power, h.p. I5

Notes: I. Pump НП43-I, automatic starting control unit АПД-I8БД (series II), the regulating equipment of starter-generators, the measuring instruments, starting unit 2С7К of the engine fire-alarm system and vibration measuring equipment are not supplied with the engine. Overtemperature controller amplifier УРТ-19А-2Т and fire detectors ДПТ-6 are supplied with the engine.

2. The gear ratio values of all the accessory units and instruments, exclusive of compressor low-pressure rotor tachometer generator ДТЭ-5Т and centrifugal speed governor ЦИ-2Б are related to the rpm values of the compressor high-pressure rotor. The gear ratio values of compressor high-pressure rotor tachometer generator ДТЭ-5Т and centrifugal governor ЦИ-IB are related to the rpm values of the compressor low-pressure rotor (see Fig.5).

3. Given in the main technical data are manometric pressure values, except otherwise stated.

4. 1% on tachometer indicator scale corresponds to:
(a) 55.2I rpm for compressor l.p. rotor;
(b) II6.77 rpm for compressor h.p. rotor.

Engine Operating Conditions

I. Engine idling rating ($H = 0$, $V = 0$, $t_H = +15°C$, $P_H = 760$ mm Hg)
- thrust, kg .... 475, max
- compressor h.p. rotor speed, rpm .... 7200 ± I00 (6I – 62.5%)
- hourly fuel consumption, kg/hr .... 480, max
- turbine outlet gas temperature, °C .... 360, max
- time of continuous operation, min .... not limited

2. Engine Main Ratings on Ground
(under standard atmospheric conditions)

Table I

Engine rating	Speed of compressor rotors rpm (per cent): Low-pressure rotor (for reference: 100% corresponds to 552I rpm)	Speed of compressor rotors rpm (per cent): High-pressure rotor (100% corresponds to 11,677 rpm)	Thrust, kg	Specific fuel consumption, kg/kgt/hr, max.	Turbine outlet gas mean temperature, °C, max
I	2	3	4	5	6
Maximum take off. Not more than 5 min of continuous operation.	7700±75 (89.5–91.5)	11,600 +50/−100 (95.5–100)	6600−150	0,620	620

[redacted]

I	2	3	4	5	6
Normal(not limited)	6850 ±75 (79.5–81.5)	[illegible] +50 −100 ([illegible]2.5–94)	5000 −2%	0,585	530
0,83 normal (ot limited)	6550 ±75 (76–78)	10,[illegible] +50 −100 ([illegible]–91.5)	4400 −2%	0,575	495 (for ref.)
0.7 normal (not limited)	6050 ±75 (70–72)	10,250 +50 −100 (87.0–[illegible].5)	3500 −2%	0,575	450 (for ref.)
0.6 normal (not limited)	5750 ±75 (66.5–68.5)	10,[illegible] +50 −100 (85–[illegible])	3000 −2%	received	420 (for ref.)
0.53 normal (not limited)	5500 ±75 (63.5–[illegible].5)	9800 +50 −100 (83–8[illegible].5)	2050 −2%	received	400 (for ref.)

Table 2

3. Engine Main Ratings in Altitude Flight (H = II,000 m, M_f = 0.75 [illegible])

Engine rating	Speed of compressor rotors, rpm (per cent)		Thrust, kg.	Specific fuel consumption, kg/kg/hr, max	Turbine outlet gas mean temperature, °C, max
	low-pressure rotor (for reference: 100% corresponds to 8521 rpm)	high-pressure rotor (100% corresponds to II.677 rpm)			
Maximum take off (not more than 5 min of continuous operation)	7900 +50 −25 (92.5–93.5)	11.[illegible] +50 −100 (97–98.5)	[illegible] −2%	0,860	630
Normal (not limited)	7450 ±75 (86.5–88.5)	10900 +50 −100 (92.5–9[illegible])	1760 −2%	0,805	540
0.83 normal (not limited)	7160 ±75 (83.5–85)	10,650 +50 −100 (90.5–91.5)	1600 −2%	0,755	505 (for ref.)
0.7 normal (not limited)	6720 ±75 (78–80)	10,250 +50 −100 (87–88.5)	1300 −2%	0,770	460 (for ref.)
0.6 normal (not limited)	6450 ±75 (75–76.5)	10.000 +50 −100 (85–86)	1120 −2%	0,780	430 (for ref.)

Notes: I. The above tabulated engine parameters are given with no account of air bleed for [illegible] needs and for cooling the [illegible].

2. With the engine running at a steady rating permissible variations in the speed of the compressor low-pressure and high-pressure rotors must be within the following limits: on the ground [illegible] ([illegible] for the low-pressure rotor and [illegible] for the high-pressure rotor); in flight [illegible] (±0.5% for the low-pressure rotor and ±0.45% for the high-pressure rotor). Permissible variations in the exhaust gas temperature must not exceed ±3[illegible] on the ground and [illegible] in flight.

[redacted]

[redacted]

3. The ambient air temperature, at which maximum fuel flow at maximum take-off rating under P_H = 760 mm Hg is limited, equals plus 15°C.
4. With the air bleed system for aircraft needs cut in on the ground or in flight at any engine rating (with the exception of maximum take-off one) the exhaust gas temperature may rise by 20°C. At maximum take-off rating JPT is limited by the ПРТ-35 overtemperature control system.
5. The engine may run at maximum take-off rating only for aircraft take-off and in emergency cases.

4. Acceleration time, i.e. the time period from the moment the engine control lever starts displacing to the moment the engine develops 95% take-off thrust, sec:
   - from idle speed .... 15, max
5. The compressor h.p. rotor speed during acceleration must not be 180 rpm less than maximum take-off rating speed.
6. During acceleration check to maximum take-off rating compressor rotor may overspeed for not over 3 sec as follows (rpm):
   (a) compressor l.p. rotor speed .... 150, max
   (b) compressor h.p. rotor speed .... 150, max
7. Exhaust gas temperature during acceleration check (average as measured by means of 12 thermocouples), °C .... 620, max

25X1

ENGINE CONSTRUCTION

25X1

Chapter II

ENGINE CONSTRUCTION

1. COMPRESSOR
(Fig. 6,7)

The engine compressor is an axial type, employing two shafts; it consists of two sections: the low-pressure section and the high-pressure section. The low-pressure and high-pressure sections of the compressor differ in mass flow and pressure head built up, their rotors running at different rpm values. The by-pass ratio at maximum take-off rating is

$$\frac{G_1}{G_2} = 2,$$

where G_1 is the air mass flow through the compressor low-pressure section;
G_2 is the air mass flow through the compressor high-pressure section.

The compressor low-pressure section comprises four stages, of which the first stage is a supersonic one. The low-pressure rotor is driven by the second turbine. The compressor high-pressure section employs ten subsonic stages. The high-pressure rotor is driven by the first turbine.

To reduce vibration overloads of the engine casings, the roller bearing supports are of the resilient damping type. Such a support comprises a resilient element (a coupling member) of the "squirrel-wheel" type and a circular oil damper (cavity E).

Multistage labyrinth seals reliably prevent oil in the bearing voids from getting inside the flow path.

The use of aluminium and titanium alloys and high quality of machining ensure high strength of low-weight compressor parts and assemblies.

(a) Compressor Low-Pressure Section
(Fig.6)

The compressor low-pressure four-stage section with one supersonic stage supplies air at high pressure ratio and moderate hydraulic losses.

The compressor low-pressure section comprises the following main units (Fig.6): front frame 2, nose bullet 25, casings with stator vane assemblies 7, rotor 5, drive shaft 13, coupling bolt 14 and deicing system circular manifold 3.

F r o n t   f r a m e 2 serves also as an inlet guide vane assembly It consists of outer casing, 26 inlet guide vanes (IGVs) inner shroud, front cover 27, rear cover 28 and bearing housing.

The vanes are attached to the outer casing and inner shroud by means of bolts, which are secured by center punching from inside. The front and rear covers are bolted to the inner shroud. The bearing housing accommodating a steel pressed-in holder is centered with respect to the inner diameter surfaces of the rear and front covers. Attached to the bearing housing are the component parts of the resilient damping support, labyrinth, sealing flanges of the roller bearing void, cover 23, bearing oil seal 24 with four bronze sealing rings, adapter 26 with jet for lubricating the roller bearing, and oil feed and scavenge pipelines.

Double-walled nose bullet 25 is attached to the bearing housing via oil seal 24. The nose bullet is fabricated of sheet aluminium alloy; the front frame, IGVs, covers, shroud and bearing housing are made of titanium.

To prevent ice formation in the IGV assembly, the vanes are heated by hot air flowing via cavities B inside the vanes. Hot air is bled from the tenth or fifth stage of the compressor high-pressure section depending on the engine operating conditions, to be supplied to the IGVs via a heat-insulated pipeline. The hot air is delivered to heat-insulated circular manifold 3 to be further distributed among vane cavities B. Air leaving cavities B flows through the slots in the inner shroud for heating the nose bullet outer shell to be discharged into the compressor flow path via the holes in the shell.

Only 23 vanes are heated with air, the remaining 3 are heated by oil, for which purpose provision is made for cavity Г in each of the three vanes. The manifold is heat-insulated and flexibly attached to the front frame to allow thermal expansion of the manifold.

The three lower vanes are used for oil delivery to and scavenge from the roller bearing void of the compressor low-pressure section.

Oil is supplied through one of the lower vanes via the pipe of oil seal 24 to the jet-and-adapter assembly 26 for lubrication of the compressor roller bearing; oil forced through oil seal 24 is also conveyed to the front roller bearing of the second turbine via the pipes installed in hold-down bolt 9 and coupling bolt 14. Some oil is tapped from adapter 26 to be supplied via a pipeline into damping cavity Е of the resilient damping support. From the roller bearing void oil is scavenged through other two vanes.

The fore flange of the front frame carries a bracket attached to the flange on top by means of six fitted bolts and intended for mounting the engine in the aircraft.

Attached to the front frame is adapter 1 where front flange carries six attachment units 29. The units constitute a part of the sealing unit installed between the engine and aircraft air intake.

The adapter is used also for cooling oil supplied from the centrifugal deaerator. Oil flow takes two and half turns circulating along the adapter cavities about the engine axis and is carried to the fuel-cooled oil cooler.

To intensify heat transfer, the adapter outer casing is provided with depressions extending heat-transfer area.

Ice detector 16 is attached to the adapter.

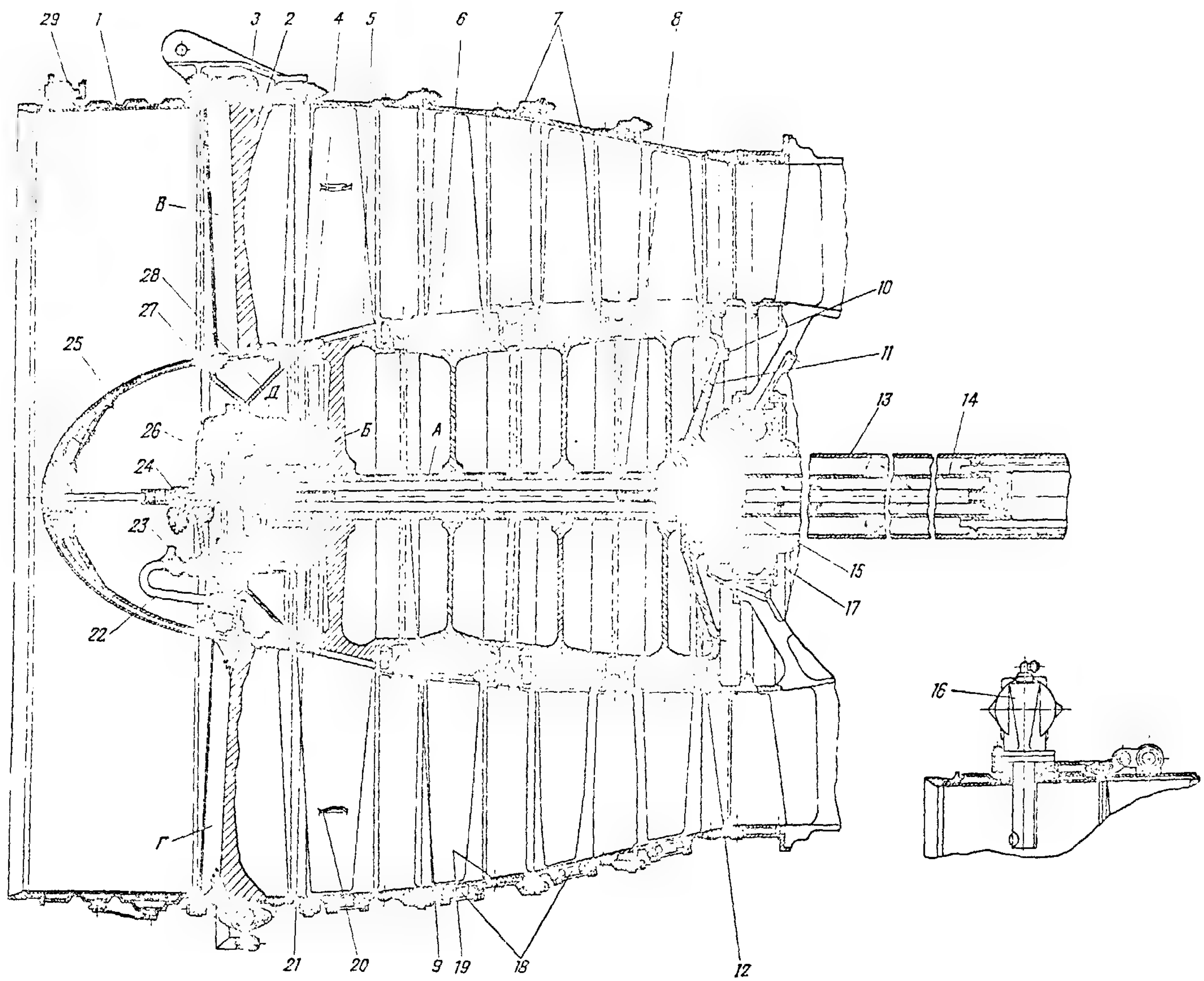

FIG. 6. COMPRESSOR LOW-PRESSURE SECTION

1 – adapter; 2 – front frame; 3 – deicing system circular manifold; 4, 19 – dowels; 5 – compressor rotor; 6 – pin; 7 – compressor casings with stator vane assemblies; 8 – tube; 9 – hold-down bolt; 10 – balance screw; 11 – rotor rear shaft; 12 – hold-down bolt abutment disc; 13 – rotor drive shaft; 14 – coupling bolt; 15 – slotted retainer; 16 – ice detector ДО-202М; 17, 21 – spherical supports; 18 – blade inspection holes; 20 – antivibration flanges; 22 – oil scavenge pipe; 23 – oil feed pipe; 24 – oil seal; 25 – nose bullet; 26 – oil jet-and-adapter assembly; 27 – front cover; 28 – rear cover; 29 – attachment unit.

Compressor low-pressure section casing consists of four component parts 7 accommodating stator vane assemblies.

The 4th stage stator assembly is designed to straighten the air flow to the axial direction. It has two rows of vanes: guide and straightener.

The ends of the guide and straightener vanes directed towards the inner rings carry threaded trunnions, whereas the outer ends of the vanes are provided with flanges. The vanes of each stage are fitted into the inner rings and are clamped by means of nuts. The flanges at the outer ends of the vanes form the outer ring of the stator vane assembly. To guard the vanes against displacement, the vanes are secured to one another by threaded dowels.

The inner rings of the stator vane assemblies of the first, second and third stages have two annular flanges each, clad with sealing compound on the inner side. The flanges in conjunction with circular serrations on the compressor discs form interstage labyrinth sealings preventing reverse flow of air.

The vanes, inner rings and casings are manufactured from aluminium alloy.

The stator vane assemblies are secured in the casings by means of dowels 19. The casing of all the four stages are provided with access holes 18 for inspection of the compressor blades in service.

Compressor low-pressure rotor 5 is of a drum-and-wheel construction; it consists of four bladed wheels and rear shaft 11 carrying abutment disc 12 for hold-down bolt 9. The wheel discs and the rear shaft are centered and connected by means of face splines and are clamped by hold-down bolt 9 mounted on spherical supports 21 and 17.

The rotor has one front and one rear journal placed on two supports; the front support is furnished with a roller bearing, taking up radial forces, and the rear support - with a ball bearing, taking up both radial and axial forces.

The rotor front journal mounting the roller bearing and labyrinth seal components is made integral with the 1st stage wheel disc. The rotor rear journal carrying a ball bearing and oil seal components is made integral with the rear hub.

The blades are dovetailed into the rotor discs. The blades are held against axial displacement by dowels 4. The dowels are locked by means of rings. Some of the bolts holding the rings and bolts 10 on rear shaft 11 are used for dynamic balancing of the rotor assembly.

The first-stage moving blades are made from titanium alloy. To improve surface finish, the blade airfoil sections are subjected to vibratory surface treatment. To reduce vibration stresses in the blades during operation of the engine, the first-stage blades are provided with flanges 20 forming an anti-vibration shroud.

The pin-type fixing of blades is used for the 2nd, 3rd and 4th stages, which makes it possible for the blades to assume under the action of gas-flow and centrifugal forces the most optimum position as for vibrations and blade-root stresses.

The blade root lugs are inserted into the grooves of the disc rim and secured by pins 6. Each pin is held in position by a shoulder from one side and by a riveted bush from the other.

The blades of the 2nd, 3rd and 4th stages are fabricated of aluminium alloy. The blade lugs are provided with bronze pressed-in bushes to increase contact strength.

[redacted]

The low-pressure compressor discs have circular edges mating with the inner rings of the stator vane assemblies to form interstage labyrinth seals preventing reverse flow of the air within the compressor flow path. The discs are manufactured of titanium alloy, the rear shaft is made of steel.

Hold-down hollow bolt 9 rests through the medium of spherical supports 21 upon the first-stage wheel disc in the front part and through the medium of a spherical ring upon abutment disc 12, driven into rotor rear shaft 11, in the rear part Inserted into the hold-down bolt is a tube for oil supply to the second turbine bearing. The tube supports are provided with rubber rings to seal the oil-contacted cavity and to prevent the hold-down bolt inner surface from cold working.

The compressor rotor rear shaft is splined to receive drive shaft 13 that transmits torque from the second turbine to the compressor low-pressure section.

Coupling bolt 14 is used to hold the second turbine axially. It has spherical support 17 and is locked by slotted retainer 15.

The coupling bolt accommodates an oil supply pipe for lubrication of the second turbine bearing. The roller bearing oil seal is a series of three labyrinth type seals.

The first seal is an oil slinging seal formed by four-start right-hand threading on the shaft and four-start left-hand threading on the mating part. The second- and third-stage seals are of the labyrinth type.

To improve the operation of the oil seal of the roller bearing void, compressed air bled from the compressor low-pressure section via the rear shaft threaded holes free of balance screws is supplied into cavity B via the holes in the rotor front shaft and circular cavity A formed between tube 8 and hold-down bolt 9.

The oil seal of the ball bearing is a series of two labyrinth-type seals. The mating surfaces of the labyrinth flanges are covered with sealing compound.

(b) Compressor High-Pressure Section
(Fig.7)

The compressor ten-stage high-pressure section makes it possible to substantially increase the pressure ratio at the compressor outlet.

The compressor high-pressure section consists of the following main units: inlet guide vane assembly 1, compressor casing 15 with stator vane assemblies and outer shrouds, tenth-stage stator vane assembly 8, rotor 3, air blow-off unit housing 5, labyrinth seal components 10 and 18, roller and ball bearings.

I n l e t   g u i d e   v a n e   a s s e m b l y 1 is designed for guiding the air flow onto the first-stage wheel. The variable incidence inlet guide vanes are controlled by an actuating mechanism to reduce vibrational loads in blading and to aid in eliminating compressor stall and surge during starting and acceleration. When actuated the IGVs turn on their axes changing the compressor inlet flow area. As a result, air flow through the IGV assembly changes and the compressor flow conditions are improved.

The IGVs may be set in one of the following two positions: at normal operating ratings - to $\alpha = 0$ and at low-speed ratings - to $\alpha = -10^{0}$.

The inlet guide vane assembly consists of outer and inner rings, guide vanes, driving ring with "forks", and vane linkage provided with a number of blocks.

[redacted]

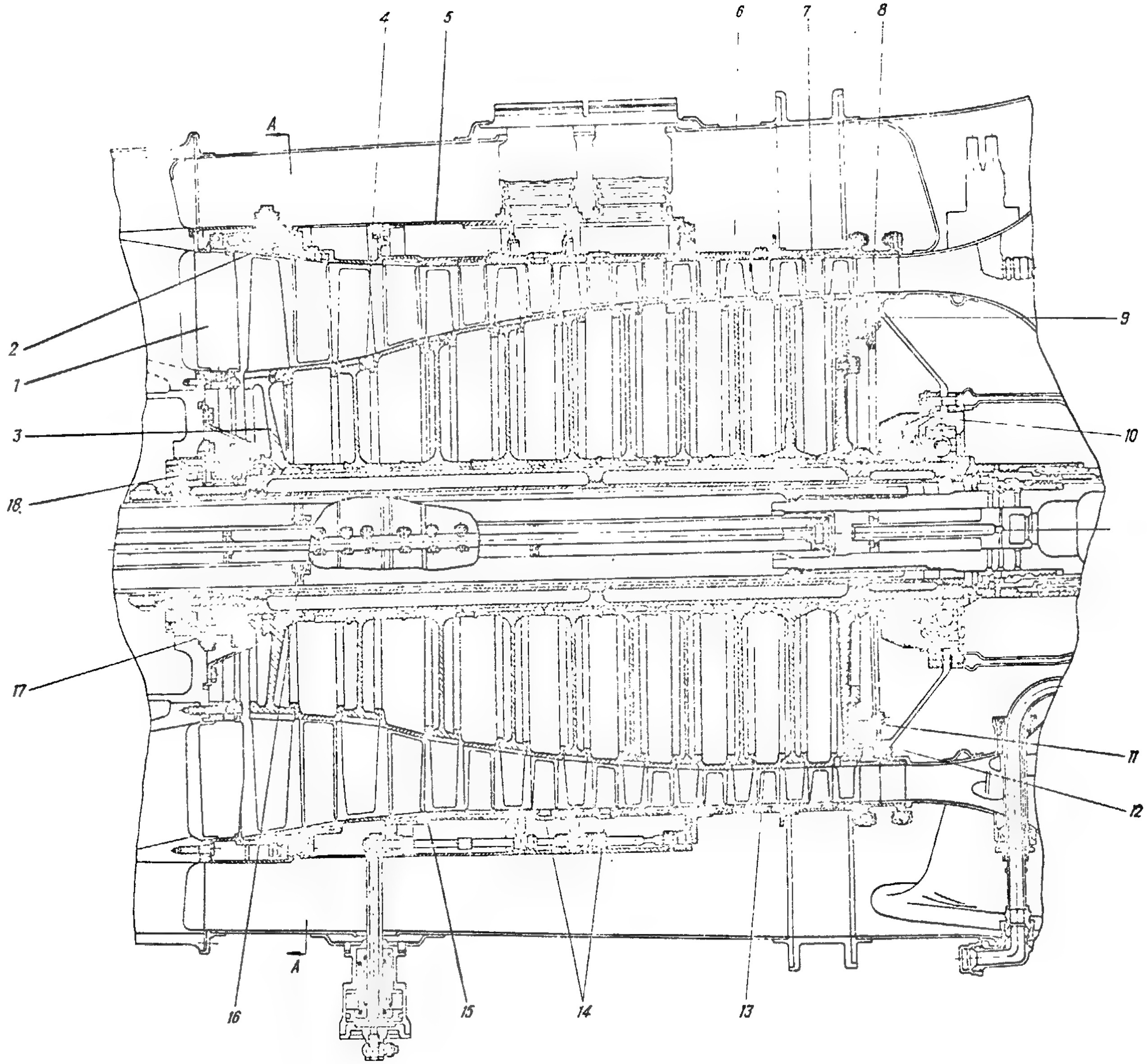

FIG. 7. COMPRESSOR HIGH-PRESSURE SECTION

1 = compressor h.p. section inlet guide vane assembly; 2 = first-stage wheel perforated outer shroud; 3 = compressor rotor; 4 = dowel; 5 = air blow-off unit housing mounted on compressor casing; 6 = working wheel shroud, 7 = stator vanes; 8 = tenth-stage stator vane assembly; 9 = cooling inserts; 10 = labyrinth flange; 11, 12 = labyrinth seal rings; 13 = interstage ring; 14 = air blow-off holes; 15 = compressor casing; 16 = rotor tube; 17 = inner coupling shaft of elastic-damping support; 18 = labyrinth seal flanges.

[redacted]

The outer ring is attached to the by-pass duct entry housing flange. The ring has 37 bosses with bronze bushes pressed-in, serving as bearings for the vane outer ends. Machined at the outer ring rear flange is a groove serving as a race for the driving ring rollers. The outer ring inside surface is provided with two case-hardened annular collars for centering compressor first-stage shroud ring 2.

The IGV assembly inner ring is attached to the flange of the drive gear housing. It consists of two halves bolted together. 37 spherical bushes are clamped between the inner ring halves.

The IGVs are made of titanium alloy. The vane trunnions are fitted with pressed-in bushes. The outer end of each vane fits into the outer ring, each of the vane inner ends fits into one of the inner ring spherical bushes via a spherical ring.

Put on the vane outer ends are turning levers, whose pins enter the fork blocks. The forks are secured to the driving ring.

The driving ring consists of six segments. Each segment is assembled of two planks with distance sleeves placed in-between. The planks are clamped by forks provided with threaded end pieces. Some of the distance sleeves are furnished with rollers.

The driving ring is capable of turning by a small angle. The turning range is limited by lugs made on one of the segments.

When turned, the driving ring imparts motion to the vanes via the forks and vane linkage. As a result, the vanes get turned to a definite angle.

The IGVs are turned by means of the hydraulic actuator operated from the automatic fuel control system. The hydraulic actuator transmits motion to the IGVs via a link hinged to the bracket which is secured to the driving ring.

The engine is equipped with an IGV position signalling system. To visually observe the position of the vanes, provision is made of a scale graduated in degrees of vane turning angle.

When the IGVs are set at $\alpha = -10^{\circ}$, an indicating light comes on in the aircraft crew cabin.

Compressor casing 15 comprises a split casing proper, guide vane assemblies 7 and working wheel shrouds 6.

The casing is made of steel and is split horizontally into two halves. It consists of a shell carrying four welded longitudinal flanges and eight half-rings on the outer surface.

The casing halves are held together along the longitudinal flanges by means of 46 bolts, of which six bolts (three at each side) are fitted bolts serving for aligning purposes.

The six half-rings on the outer surface of the casing shell centre section make up three circular flanges forming two independent cavities for receiving air from the 4th and 5th stages of the compressor. The flange made integral with the front ring is used for attachment of the air blow-off unit housing. Every stator vane assembly 7 (from the 1st to the 9th stage) arranged inside the compressor casing comprises two half-rings mounting the vanes. The vanes are dovetailed into the half-rings in a cantilever manner. Each half-ring is secured to the compressor casing shell by eight screws. The half-rings are made of titanium alloy.

The casing shell and the half-rings of the stator vane assemblies of the 4th and 5th stages have two rows of holes 14 drilled between the grooves receiving the vanes and serving for air blow-off.

[redacted]

The stator vanes are made of titanium alloy. Installed between the stator vane assemblies in the casing are solid working wheel shrouds 6 turned from titanium alloy. To exclude buckling, the shrouds are fastened to the compressor casing shell by rews.

To ensure minimum radial clearances between the stator shrouds and the compressor rotor blades, the inner cylindrical surfaces of the shrouds are coated with a sealing compound. In the area opposite to the moving blades of the 2nd stage the sealing compound is applied on the compressor casing. The rear flange of the compressor casing is bolted to tenth-stage stator vane assembly 8, the front flange being attached to first-stage wheel perforated outer shroud 2. The shroud is made of steel. It has two nitrated locating surfaces and an attachment flange. This shroud makes a telescopic joint between the compressor casing and the inlet guide vane assembly.

The outer ring of the inlet guide vane assembly and the first-stage wheel shroud form a circular chamber over the perforated wall of the first-stage wheel shroud. The perforated wall has 2520 holes 3.5 mm in diameter. It is located in around the first-stage moving blades.

The use of the perforated wall with the annular space around the first-stage moving blades aids in eliminating compressor stall and surge in operation and reduces vibration loads in the first-stage stator vanes and rotor blades.

10th stage stator vane assembly 8 makes the compressed air stream flow in the axial direction. It comprises a ring with two outer flanges and press-fitted vanes, arranged in two rows and dovetailed into the ring. The vanes of the front row act as guide vanes, the vanes of the rear row serving for straightening the air stream.

The inner flanges of the vanes forming an inner shroud are provided with shanks making up an inner circular flange of the guide vane assembly. The vanes are made of steel.

The front flange of the guide vane assembly is secured to the compressor casing, the rear flange receiving the combustion chamber flange. Clamped between the flange formed by the shanks of the vanes and the combustion chamber inner casing flange is the flange of outer air labyrinth ring 12. The inner labyrinth ring is held to the outer ring by bolts. Both labyrinth rings accommodate sealing inserts 9. Working against these inserts are the circular ridges of the rotating labyrinth attached to the compressor rotor.

The labyrinth air seal made up by outer 12 and inner 11 rings and the compressor rotor rotating labyrinth part reduces air leakage from the compressor flow path and serves for partially taking up axial loads, acting on the ball bearing of the compressor high-pressure rotor.

Air blow-off unit housing 5 consists of a shell, two flanges and two ribs welded to the shell. Welded to the housing are six flanged pads to mount six throttle valves, whose axles are linked up to the hydraulic actuators by means of levers splined on the axles. The air blow-off housing shell has four bushes supplying air for aircraft services and two bushes for bleeding air for the de-icing systems of the engine and the aircraft air intake.

The air blow-off unit housing is mounted on the compressor high-pressure section to form three independent annular cavities together with the casing. The two front bushes receive ducts connecting the air cavity aft of the 4th stage of the

compressor high-pressure section with the air bleed system delivering compressed air for pressurizing and ventilating the aircraft cabin.

Inserted into two rear bushes are two ducts connecting the air cavity aft of the 5th stage of the compressor high-pressure section to the air bleed system supplying compressed air to the wing and fin anti-icing systems. Screwed into the holes of the two remaining bushes are ducts connecting the air cavity aft of the compressor 5th stage with the de-icing systems of the engine and the aircraft air intake.

Compressor high-pressure rotor 3 is of a drum-and-wheel construction; it is composed of a shaft, ten bladed wheels, and interstage rings 13.

The wheel assemblies are installed on a common shaft, being centered thereon by means of rectangular splines; they are held by means of nuts to avoid any displacement of the wheel assemblies in the axial direction.

Each wheel assembly consists of a disc and a number of blades dovetailed around the outer perithery of the disc. The discs are provided with a hub having internal rectangular splines for connection to the rotor shaft. The first eight discs and the blades of the first eight stages are made of titanium alloy. The wheel assemblies of the 9th and 10th stages are fabricated from steel.

After the nuts are tightened up, the disc hubs are clampted together. The discs of the 1st, 9th and 10th stages get distorted so that their central sections are arranged on the shaft in a fan-shaped manner, which substantially aids to the rigidity of the rotor.

To provide a smooth flow path and to secure the blades in the discs against displacement in the axial direction, the wheel discs are interlaid with interstage rings 13, which are aligned relative to the discs by means of projections fitting into the disc rims. The interstage rings are held against turning by dowels fitting into respective recesses in the disc rim. Each interstage ring has two holes communicating the rotor interior space with the engine breathing system.

The blades of the first, second and third stages are held against axial displacement in the discs by dowels 4, whereas the blades of the 10th stage are retained by the shoulder of the labyrinth, which is secured to the disc rim by means of a "gun" type lock, and to the disc diaphragm - by screws.

The compressor rotor shaft is made of steel. The front journal of the rotor shaft mounts a roller bearing and the component parts of the two-stage oil sealing labyrinth. The outer ring of the roller bearing is secured by a nut in inner coupling member 17 of the damping support. The inner coupling member and bearing ring are provided with resilient elements of the "squirrel-cage" type. Two grooves are made on the outer surface of the inner coupling member to receive oil sealing rings forming damping cavity E between the holder and inner coupling member 17. Oil is fed into the damping cavity from the engine oil main line via drilled passages in the drive gear housing.

The journal internal splines are used for mounting the driving gear of the upper and lower drive gear boxes. The gear is held against displacement by two locking pins.

Mounted on the outer surface splines of the rear journal are several component parts of the two-stage oil sealing labyrinth and a ball bearing. The internal splines at the end of the rear shaft journal are designed to receive the first turbine rotor shaft. Three rows of holes are drilled in the rear shaft journal for draining

[redacted]

oil from the front roller bearing of the second turbine. Tube 16 mounted inside the rotor shaft is intended to prevent oil accumulation. The tube is secured in position by two dowels.

To reduce heat transfer into the oil, the wall of labyrinth rear outer flange 18 is coated with a layer of heat insulation, whereas the space between the outer and inner flanges of the labyrinths is blown with air tapped from the by-pass duct.

2. BY-PASS DUCT ENTRY HOUSING WITH ACCESSORY DRIVE GEAR BOXES (Fig.8)

The by-pass duct entry housing is located between the low-pressure and high-pressure sections of the compressor and is designed for dividing the air flow after the compressor low-pressure section into two streams, as well as for accommodating the components of the central drive, for attachment of the accessory drive gear boxes and for mounting the ball and roller bearings of the compressor low-pressure and high-pressure rotors.

The air leaving the compressor low-pressure section is divided into two streams, one of which is directed into the annular by-pass duct, and the other into the high-pressure section of the compressor.

The accessory drive housing is mounted inside the annular box of the by-pass entry housing central part, whereas the drive gear boxes are installed on the upper, lower and right-hand outer flanges of the by-pass duct entry housing. Rotary motion from the driving gears fitted onto the shafts of the compressor low-pressure and high-pressure rotors to the gears of the accessory gear boxes is transmitted through the medium of splined shafts arranged in the upper, lower and upper r.h. struts of the by-pass duct entry housing.

T h e   b y - p a s s   d u c t   e n t r y   h o u s i n g (Fig.8) is cast of magnesium alloy. It is comprised of outer rim 2, inner circular box 4, flow dividing ring 17 and six hollow struts. The flow dividing ring and the struts are given a streamlined shape.

Front flange 1 of the outer rim carries the fourth-stage casing of the compressor low-pressure section, rear flange 20 being used for attachment of the forward casing of the combustion chamber.

The upper and lower parts of outer rim 2 incorporated in the by-pass duct entry housing are furnished with external bosses located opposite the vertical struts and provided with flanges 18 and 10 to carry the upper and lower drive gear boxes (21 and 11) respectively. Another flange provided on the upper right-hand portion of the housing opposite the strut is used for attachment of the right-hand drive gear box. Ignition unit СКНА-22-2А is secured on the top to the left of flange 18 to which the upper drive gear box is attached. The flange opposite the upper left strut is used for attachment of the upper drive gear box breathing pipe.

The studs on the outer flange of the front part of inner box 4 serve for attachment of the bearing oil sealing labyrinth. The flange at the rear part of the inner box carries accessory drive gear housing 15.

The by-pass duct entry housing has holes and passages for breathing and oil supply to the bearings of the drives and the compressor low-pressure and high-pressure rotor shafts.

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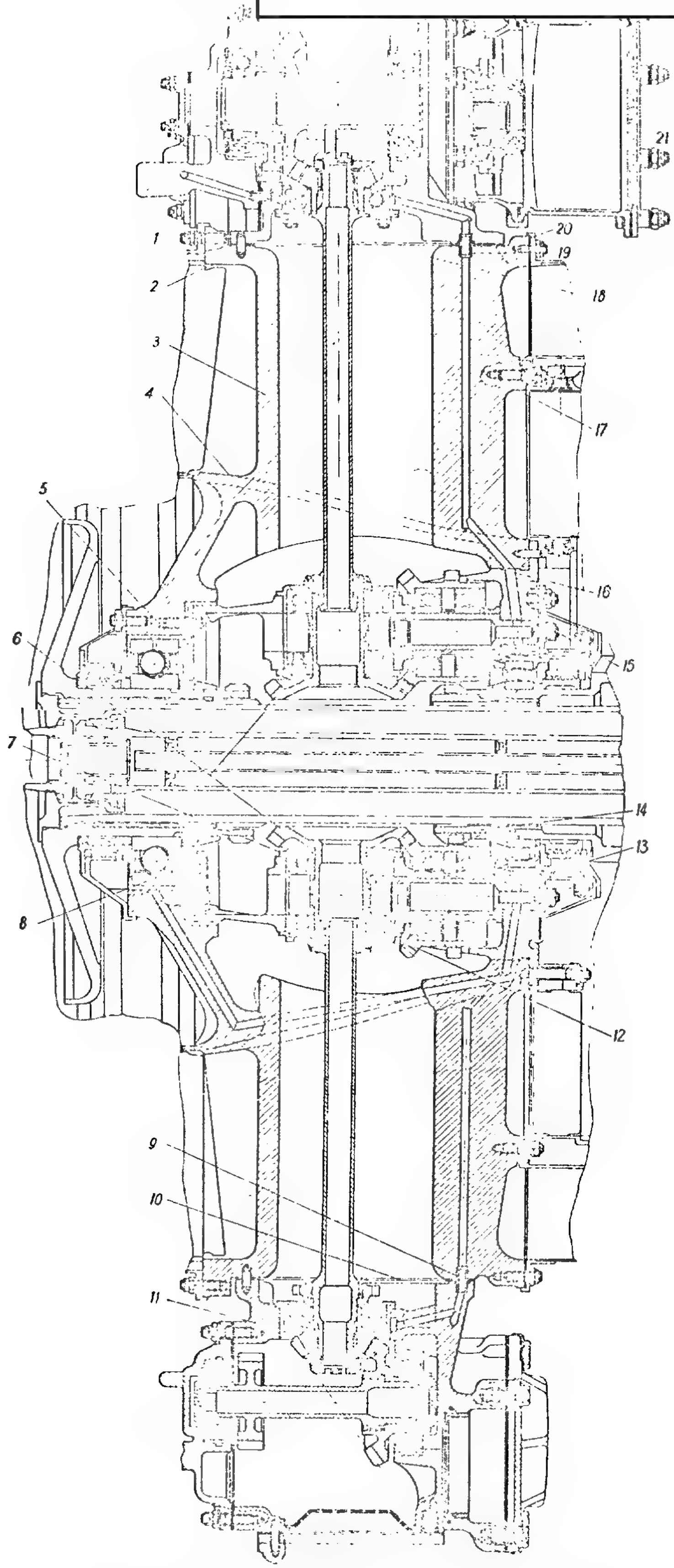

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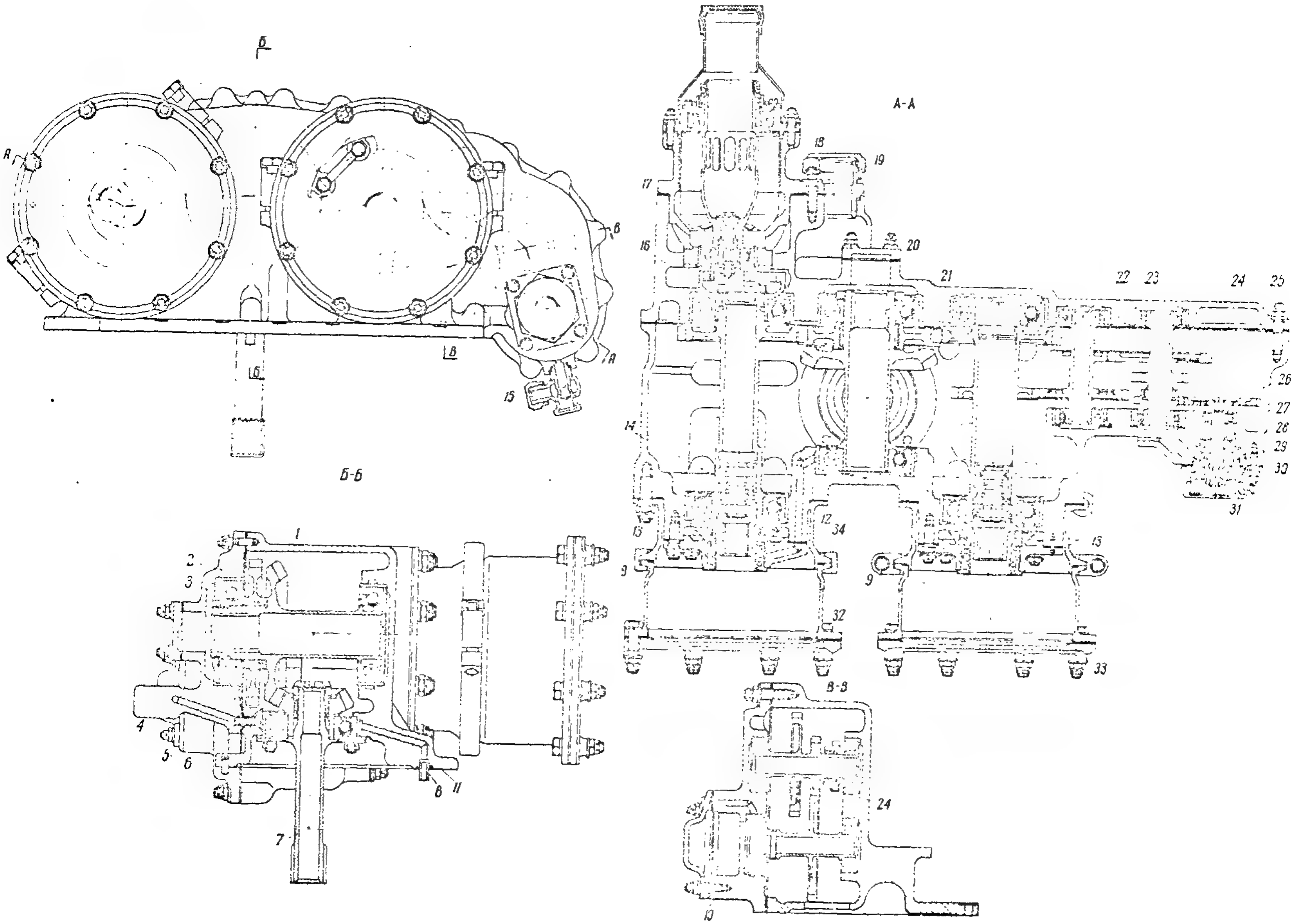

FIG. 9. UPPER DRIVE GEAR BOX

1 – upper drive gear box housing; 2 – box cover; 3 – gear, 4 – driving gear; 5 – oil transfer pipe; 6 – driving bevel gear; 7 – splined shaft, 8 – oil transfer pipe; 9 – quick-disconnect clamp; 10, 11 – flange; 12 – oil slinger, 13 – adapter, 14 – slipping clutch; 15 – swivelling connection; 16 – gear, 17 – gasket, 18 – centrifugal breather, [illegible] pipe connection; 20 – cover; 21 – left-hand gear; 22 – right-hand gear; 23, 24, 25 – idle gears; 26 – tachometer generator drive shaft; [illegible] istance sleeve; 28 – oil slinger; 29 – adapter, 30 – labyrinth, 31 – cover; 32 – adapter; 33 – cover; 34 [illegible] st flange; 35 – gear.

[redacted]

The flange of the flow dividing ring of the by-pass duct entry housing carries the inlet guide vane assembly of the compressor high-pressure section.

A c c e s s o r y d r i v e h o u s i n g 15 is cast of magnesium alloy and is designed for arrangement of the spur and bevel gears and the bearings of the central drive, as well as of the roller bearing of the compressor high-pressure section rotor.

The rear part of the accessory drive housing has the pressed-in holder of the damper support accommodating the roller bearing of the compressor high-pressure rotor. The accessory drive housing has holes and passages for breathing purposes and for oil supply to the drive bearings and to the roller bearing of the compressor high-pressure rotor shaft.

The gears accommodated in the accessory drive gear boxes are rotated by the driving bevel gears of the central drive. Lubrication and cooling of the central drive gear bearings are accomplished by supplying oil from the oil delivery line (downstream of the filter) via oil transfer pipe 9, a system of passages and recesses in the by-pass duct entry housing and in the accessory drive housing, and through the holes in the axles and the bearing holder.

The parts accommodated in the upper and right-hand drive gear boxes are lubricated with oil supplied from the passages of the by-pass duct entry housing via oil transfer pipes and the respective system of passages in the housings and drive gear box covers. Oil drain from the upper and right-hand drive gear boxes and from the accessory drive housing is accomplished through the hollows of the two vertical struts and one upper right-hand strut of the by-pass duct entry housing as well as through the holes in the accessory drive housing into the lower drive gear box.

The holes provided on the top of the accessory drive housing tapered portion and on the top of the rear flange are intended for breathing purposes.

T h e u p p e r d r i v e g e a r b o x (Fig.9) serves for attachment of the accessory units and accommodation of the drive gears.

Installed on the upper drive gear box are the following accessory units: two starter-generators СТГ-12ТВМО, centrifugal breather ЦС-30 and compressor high-pressure rotor tachometer generator ДТЭ-5Т. The starter-generators and the tachometer generator are mounted on the flanges of the box proper, whereas the centrifugal breather is attached to the flange of the box cover.

The skeleton diagram of the upper drive gear box mechanism is presented in Fig.5. The upper drive gear box consists of box housing 1 (Fig.9), cover 2 and the accessory drive components. The box and its cover are cast of magnesium alloy.

Lower flange 11 of the box rests on the upper flange of the by-pass duct entry housing. Attachment of the accessory units is accomplished through the use of flanges provided on the box and on the cover. Secured to two round flanges of the box are titanium adapters 13 and 32 mounting two starter-generators СТГ-12ТВМО. The rotor shank of each starter-generator is coupled to the shaft of gears 21 or 22 by means of torque limit clutch 14. Compressor high-pressure rotor tachometer generator ДТЭ-5Т is mounted on the square flange of the box through titanium adapter 29. The tachometer generator square shank is engaged with drive geared drive shaft 26.

Flange 10 made on a boss of the box cover is designed to attach the cover of the stand-by drive. The other flange on the box cover is used for attachment of centrifugal breather 18. Paronite gasket 17 is placed between the breather flange

and the flange of the box cover. The centrifugal breather is driven from the shaft of left-hand gear 21 via internally meshed gear 16.

The drive box cavity under the cover communicates with the cavities of the by-pass duct entry housing and the shaft tube incorporated in the combustion chamber assembly, for which purpose an external pipe is laid out from connection 19 located on the box cover.

T h e r i g h t - h a n d d r i v e g e a r b o x (Fig.10) is intended for installation of centrifugal governor ЦР-1В limiting the speed of the compressor low-pressure rotor, and compressor low-pressure rotor tachometer generator ДТЭ-5Т, as well as for accommodation of their drive gears.

Centrifugal governor ЦР-1В is attached to the box proper, tachometer generator ДТЭ-5Т - to the box cover. The skeleton diagram of the accessory drives incorporated in the right-hand drive gear box is presented in Fig.5.

The right-hand drive gear box comprises box housing 2, cover 1 and the accessory drive components. The box and its cover are cast of magnesium alloy.

The box and the cover are provided with flanges for attachment of units ЦР-1В and ДТЭ-5Т. Adapter 20 made of aluminium alloy and mounted on the box flange is designed for attachment of centrifugal governor ЦР-1В with the aid of quick-disconnect clamp 22. The governor splined shank is coupled to the shaft of drive gear 21. To provide a tight joint, a rubber ring is placed between the adapter flange and the flange of the centrifugal governor. Flange 24 on the box is used for attachment of the shaft tube breathing pipe.

A boss with swivelling connection 23 is provided on the box to the left of the centrifugal governor attachment flange to connect the external oil drain pipe running from the upper drive gear box.

Attached to the box cover flange is titanium adapter 19 for mounting compressor low-pressure rotor tachometer generator ДТЭ-5Т. The tachometer generator shaft square shank is engaged with geared shaft 13. The right-hand drive gear box is attached to flange 8 on the by-pass duct entry housing.

T h e l o w e r d r i v e g e a r b o x (Fig.11) serves for attachment of accessories, arrangement of drive gears, installation of oil filter МФС-30 and connection of the engine lubricating oil system, as well as for attachment of the drain tank.

The lower drive gear box carries the following accessory units: fuel regulating pump НР-30, fuel booster pump ДЦН-44-ПЗТ, compressor high-pressure rotor centrifugal speed governor ЦР-2В, hydraulic piston-type pump НП43-1, main oil pump ОМН-30, oil scavenging pump МНО-30 and centrifugal deaerator ЦВО-СС-30. Apart from the drives to the above units, the lower drive gear box incorporates one stand-by drive used for manual cranking of the compressor high-pressure rotor.

The skeleton diagram of the lower drive gear box mechanism is given in Fig.5.

The lower drive gear box consists of box housing 12, cover 29, filter housing 23, the accessory drive components and adapters 1, 28, 19, 5 and 16 for mounting the accessory units.

The box housing and cover are cast of magnesium alloy.

Attached to the box rear wall on upper left flange 4 is titanium adapter 5 for mounting fuel regulating pump НР-30; upper right-hand flange 15 mounts aluminium adapter 16 for installation of hydraulic pump НП43-1. These accessory units are secured to the adapters with the aid of quick-disconnect split clamps, the joints

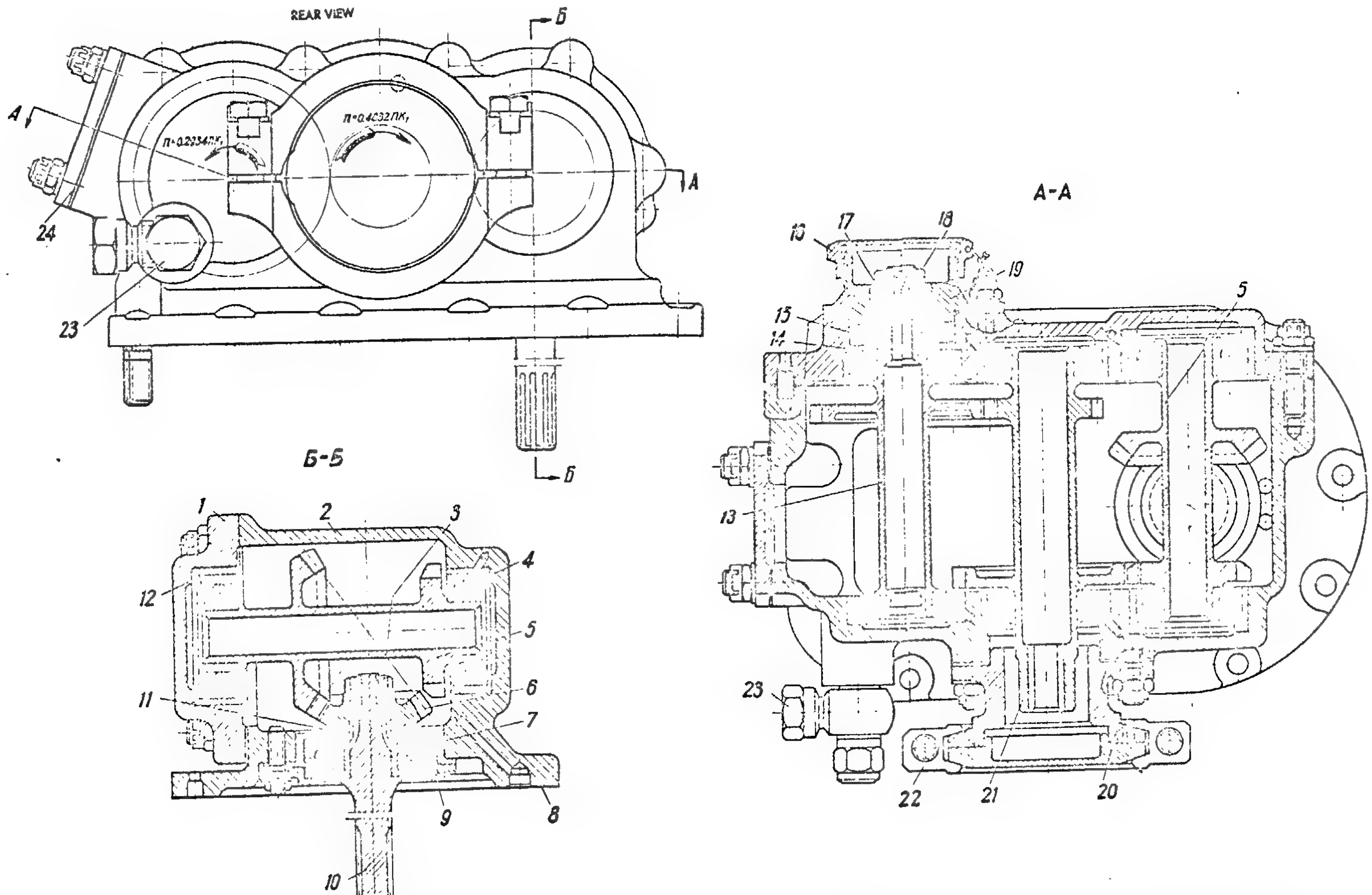

FIG. 10. RIGHT-HAND DRIVE GEAR BOX

1 – drive gear box cover; 2 – drive gear box housing, 3 – nut; 4 – adjusting ring; 5 – double ring gear; 6 – driving bevel gear; 7 – ball bearing; 8 – flange; 9 – thrust flange; 10 – splined shaft; 11 – adjusting ring; 12 – adjusting ring; 13 – shaft; 14 – adjusting ring; 15 – oil slinger; 16 – cover; 17 – labyrinth seal; 18 – nut; 19 – adapter; 20 – adapter; 21 – double ring gear; 22 – clamp; 23 – swivelling connection; 24 – flange.

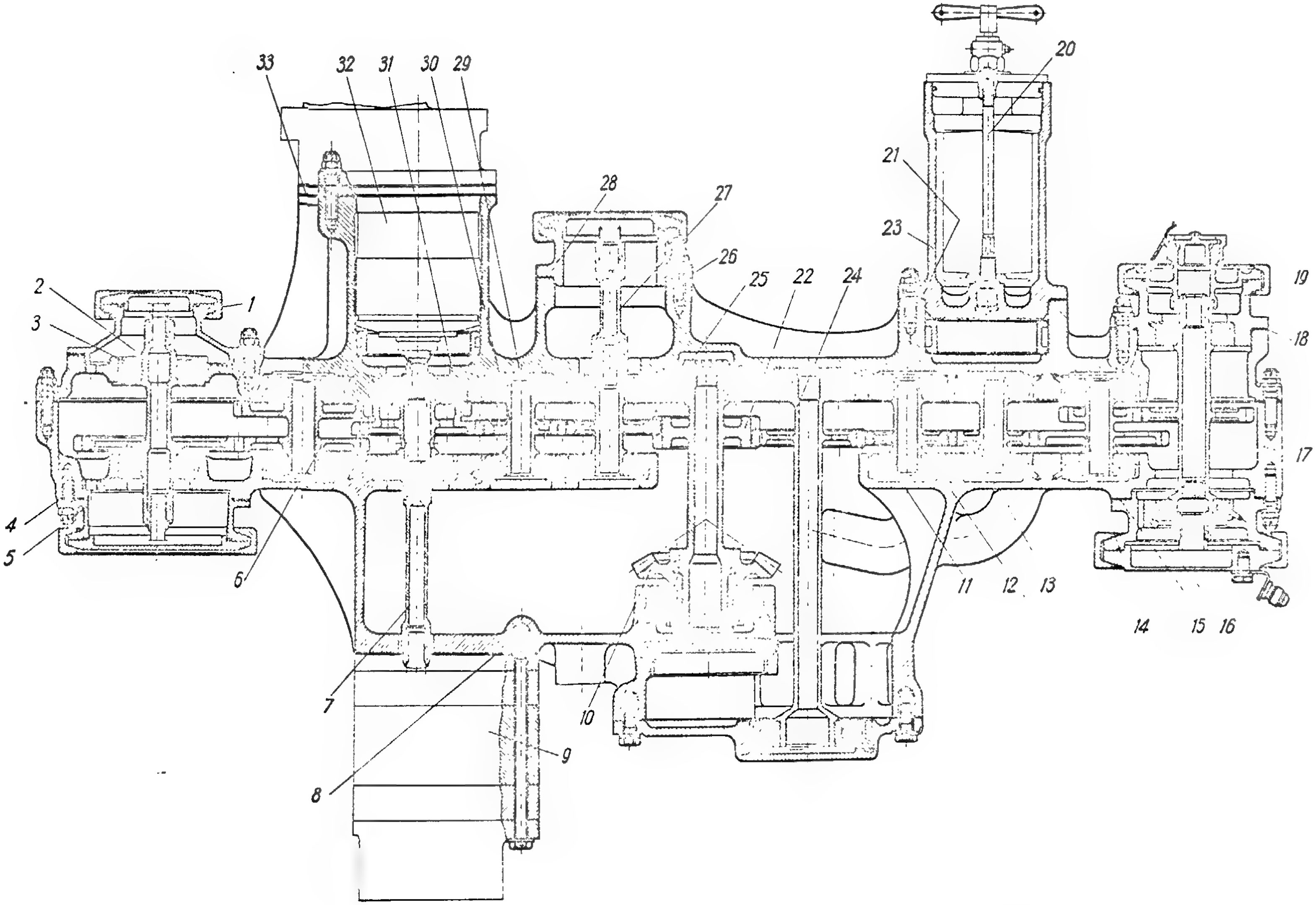

FIG. 11. LOWER DRIVE GEAR BOX

1, 5, 16, 19, 28 – adapters; 2, 6, 11, 13, 17, 24, 25, 30 – gear wheels; 3, 4, 8, 15, 18, 21, 26, 33 – flanges; 7, 27 – coupling shafts, 9 – oil scavenging pump; 10 – driven gear; 12 – drive gear box housing; 14, 31 – double ring gears; 20 – stud; 22 – driving gear; 23 – filter housing, 29 – drive gear box cover; 32 – deaerator.

between the flanges are sealed by means of rubber rings. Lower flange 8 carries МНО-30 oil scavenging pump 9, the joint being sealed by a paronite gasket. The box rear wall carries also two pipe connections: the lower one is used for installation of a sensor for measuring oil temperature at the inlet to the main oil pump, and the upper one – for oil supply to the bearings of the compressor high-pressure rotor and the first turbine rotor; a drain cock is installed at the bottom portion of the rear wall.

The lower flange of the box housing is used to mount the main oil pump. A paronite gasket and a screen are placed between the pump flange and the box housing flange. The drain tank is attached through the medium of two bosses on the box bottom and one boss on the box cover.

Drive gear box cover 29 has five flanges. Three of the flanges are used for installation of adapters 1, 28 and 19 made of aluminium alloy and designed for mounting accessory units with the use of quick-disconnect clamps. Adapter 1 carries centrifugal governor ЦР-2В, adapter 28 receives fuel booster pump ДЦН-44-ПЗТ. Adapter 19 is installed on the stand-by drive flange to be used for manual cranking of the rotor with the use of a special wrench. The joints between the flanges are sealed by rubber rings. Flange 33 is intended for mounting centrifugal deaerator ЦВС-40-30, flange 21 for installation of filter housing 23 cast of magnesium alloy.

Quick-detachable filter МФС-30 is accommodated in the filter housing and secured on stud 20. A pipe connection is driven into the front end face of the filter housing to receive the pipe-line for oil supply to the front frame in order to lubricate the bearings of the compressor low-pressure rotor and second turbine rotor. The joints between the attachment flanges and the flanges of the centrifugal deaerator and filter housing are sealed with paronite gaskets.

Apart from the five flanges the cover of the lower drive gear box is provided with one more flange for attachment of the oil pipe branch conveying oil from the oil tank to the main oil pump, and with two bosses into which a magnetic plug is driven and a pipeline is connected for scavenging oil from the front frame sump of the compressor low-pressure section.

All the gears of the lower drive gear box are enclosed in the cavity formed by drive gear box housing 12 and cover 29.

Lubrication of the gears and bearings of the lower drive gear box is accomplished by splashing oil in the box. Oil is drained from the upper and right-hand drive gear boxes and the drive gear housing via the struts of the by-pass duct entry housing and ports in the diaphragm of lower drive gear box housing 12. Oil accumulated in the box is drawn by the scavenging element of the main oil pump to be carried through the passages in the lower drive gear box housing and cover into the centrifugal deaerator.

3. COMBUSTION CHAMBER
(Fig.12)

The combustion chamber is of a cannular construction; it is arranged between the compressor high-pressure section and the first turbine.

The combustion chamber comprises the following assemblies: diffuser 33, inner casing 13, twelve flame tubes 14 with transition liners 17, diaphragm 34, shaft

tube 15 with heat-insulating layers, front outer casing 4, engine hanger housing 7, rear outer casing 16, air blow-off valve by-passing compressed air from the compressor high-pressure section into the engine outer duct, and pipes of the air, lubricating oil, breathing and internal fire-fighting systems.

Flame tubes 14 are arranged in an annular space between diffuser middle casing 20 and combustion chamber inner casing 13. The diffuser middle casing and the inner casing of the combustion chamber form a profiled circular diffuser in the front part, in which the velocity of the air stream at the entrance to the flame tubes is reduced with minimum hydraulic losses.

Diffuser 33 of the combustion chamber is welded from sheet alloy steel and represents a load-carrying unit of the engine.

The diffuser consists of outer 8 and inner 20 casings, coupled by means of twelve hollow profiled struts 9.

Outer casing 8 is provided with two circular flanges. The front flange is used to attach hanger housing 7, the rear flange receiving rear outer casing 16.

The diffuser middle casing has three circular flanges. The front flange is used for attachment of the tenth stage stator vane assembly 22 of the compressor high-pressure section. The middle flange is employed for attachment of diaphragm 34. Rear flange 21 is used for attachment of the first turbine nozzle diaphragm assembly.

The diffuser middle casing constitutes the inner surface of the engine by-pass duct.

Diffuser struts 9 on middle casing 20 carry twelve welded flanges for attachment of fuel burners 10, and twelve threaded bushes receiving flame tube hangers 11.

The diffuser middle casing has holes drilled at bottom in front of the turbine nozzle diaphragm assembly attachment flange; these holes serve for draining fuel accumulating in the diffuser during engine starting.

Inner casing 13 of the combustion chamber comprises shroud 24 made of sheet steel, inner casing ring 45 and support 23 for the bearing of the compressor high-pressure rotor. The casing shroud is strengthened by circular stiffener ribs 25.

Welded to the shell outer surface is deflector 37 forming twelve cavities that blend into a circular duct in rear deflector 31 for turbine cooling air supply. The flange of inner casing support 23 carries a compressor labyrinth and the stator vane assembly of the tenth stage of the compressor high-pressure section. Flange 32 of the inner casing is used also to secure diaphragm 34, whereas rear flange 27 receives the support of the nozzle diaphragm assembly and the support of the first turbine rotor roller bearing.

Twelve flame tubes 14 are accommodated in the combustion chamber diffuser. The flame tubes are numbered counter-clockwise, looking from the turbine end. The upper left-hand flame tube relative to the engine vertical axis is considered flame tube No.1. Each flame tube consists of a head and eight cylindrical sections welded to each other. The flame tube inner surfaces are covered with heat-resistant enamel.

Each of flame tubes No.2 and No.11 is provided with a hole with a floating washer to receive ignition plug 12 used for igniting fuel during starting of the engine. Fuel in other flame tubes is ignited by flames propagated from these tubes via cross-ignition tubes which are connected by couplings 36.

For air supply into the combustion zone and into the mixing zone, the 3rd, 4th, 6th and 7th sections of each flame tube are provided with holes. To provide a cool-

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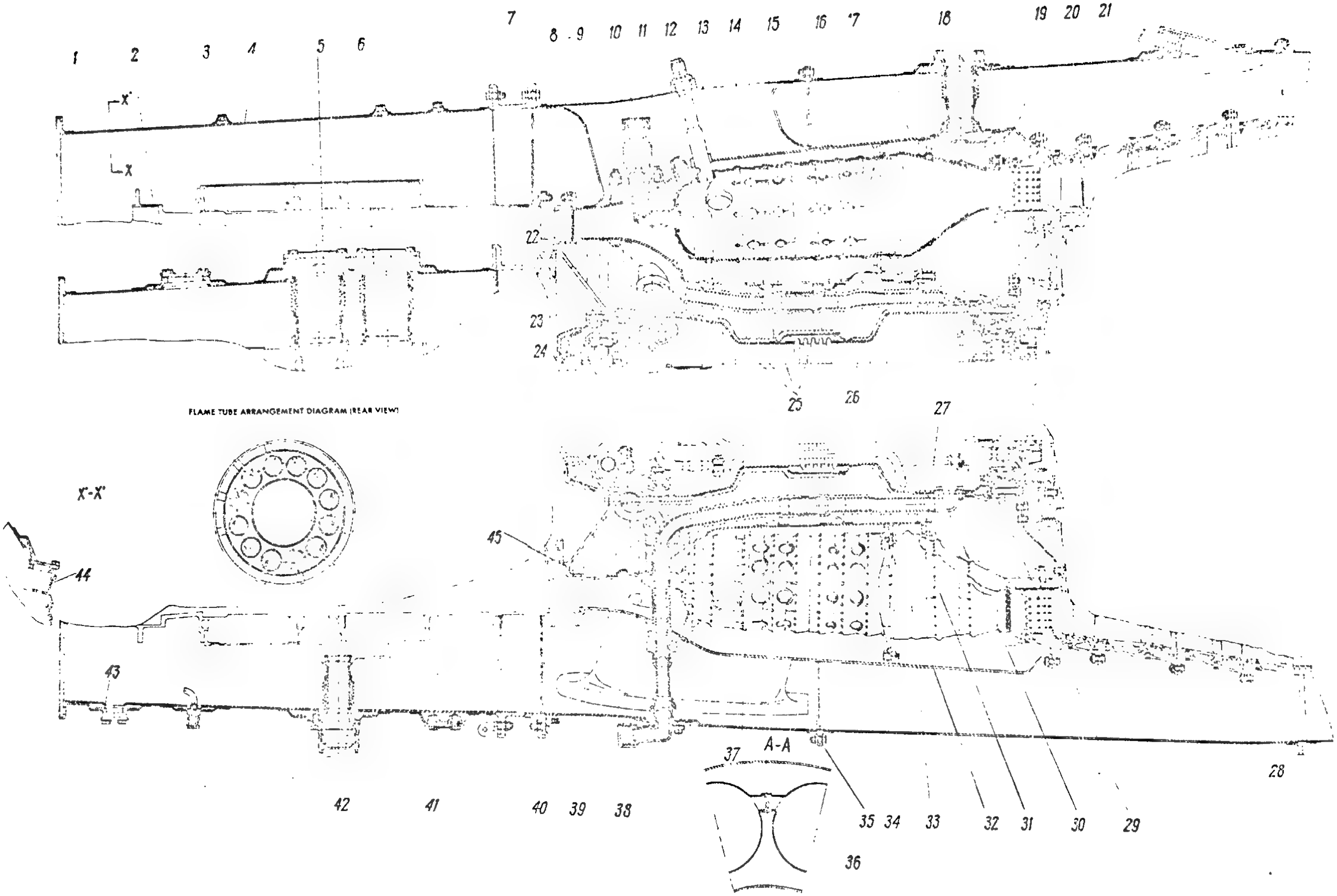

FIG. 12. COMBUSTION CHAMBER

— front casing flange; 2 — flange for attachment of hydraulic actuator controlling air blow-off shutters; 3 — bosses for attachment of ignition system cables, 4 — front outer casing, 5, 6 — air bleed ducts, 7 — engine hanger housing; 8 — diffuser outer casing; 9 — diffuser strut; 10 — fuel burner, 11 — flame tube hanger, 12 — ignition plug; 13 — inner casing; 14 — flame tube, 15 — shaft tube; 16 — rear outer casing; 17 — transition liner, 18 — air bleed duct; 19 — first turbine nozzle diaphragm assembly; 21 — first turbine attachment flange, 22 — compressor tenth stage stator vanes; 23 — inner casing support, 24 — inner casing shroud, 25 — stiffeners, 26 — shaft tube heat insulating layer, 27 — inner casing rear flange, 28 — rear casing rear flange, 29 — shaft tube flange, 30 — flange, 31 — rear deflector, 32 — diaphragm attachment flange, 33 — diffuser, 34 — diaphragm, 35 — rear casing front flange; 36 — coupling; 37 — inner casing deflector; 38 — pipe supplying oil to bearings, 39, 40 — ferrules for attachment of air by-pass pipes, 41 — support, 42 — air bleed duct, 43 — flange for attachment of IGV position indicator, 44 — flange for attachment of hydraulic actuator rod support, 45 — inner casing ring.

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ing air blanket inside the flame tubes, the front part of each section has holes allowing air entry into the flame tubes.

Welded to the rear part of the flame tube 8th section is a ring that forms a telescopic joint with transition liner 17.

The flame tube transition liner is of a welded construction. It consists of three portions. For additional rigidity, the transition liner carries a welded ring in the front part and a flange of the frame type in the rear part. The inner surfaces of the transition lines are covered with heat-resistant enamel.

The outer flanges of the transition liners are bolted to the outer flange of first turbine nozzle diaphragm assembly 19. The inner flanges in the rear part of the transition liners are installed into the annular recess of the first turbine nozzle diaphragm assembly flange; due to the clearance thus provided, a telescopic joint is obtained.

Shaft tube 15 is welded from sheet steel. It is made up of two parts (front and rear) coupled with the aid of a corrugated expansion piece. Each part has a cavity formed by the inner and outer shells of the shaft tube. The shells are welded to flanges. The front flange of the shaft tube is attached to the support of the compressor high-pressure rotor bearing, the rear flange being secured to the support of the first turbine rotor bearing.

The shaft tube interior serves as an oil cavity which accumulates oil used for lubrication and cooling of the compressor high-pressure rotor bearing and the first turbine rotor bearing.

The outer surface of the shaft tube is lined up with layer 26 of heat-insulating material. The heat-insulating layer serves to prevent the oil inside the shaft tube from overheating.

Hanger housing 7 is made of a titanium alloy. The outer circular groove of the hanger housing, formed by its flanges, is used to attach brackets for fastening the engine to the aircraft. The front flange of the hanger housing is attached to the front flange of the combustion chamber outer casing, the rear flange receiving the outer front flange of the diffuser.

Front outer casing 4 is welded of titanium alloy. It constitutes a load-carrying unit of the engine. Studded to the front flange of the outer casing is the by-pass duct entry housing, assembled with the compressor low-pressure section. The rear flange serves for attaching the front outer casing to hanger housing 7. The inner surface of the front casing forms the circular flow path of the engine by-pass duct.

Welded at the right-hand bottom part of the front outer casing is support 41 intended for attachment of a bracket to which sensors of engine operating parameters are secured. The upper part of the front outer casing has welded flange 44 designed for attachment of the sealing device through which the rod of the hydraulic actuator is passed to control the IGVs of the compressor high-pressure section. Welded at the bottom part of the casing is flange 43 for attachment of the IGV position indicator.

Rear outer casing 16 is welded of titanium alloy sheets. Front flange 35 of the rear casing is bolted to the combustion chamber diffuser, rear flange 28 receiving the turbine nozzle diaphragm assembly flange. The inner surface of the rear outer casing provides a further flow path of the engine outer duct. The rear outer casing carries a flange on top to attach the air blow-off valve by-passing compressed air aft of the compressor tenth stage into the engine outer duct.

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The air blow-off valve (Fig.13) is designed for by-passing compressed air discharged from the compressor high-pressure section into the engine outer duct during starting in order to improve the engine starting characteristics.

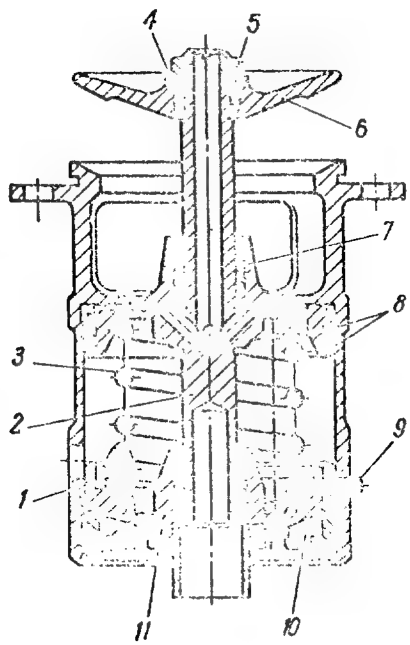

FIG. 13. AIR BLOW-OFF VALVE
1 – cylinder; 2 – rod-and-piston assembly; 3 – spring; 4 – sphere; 5 – nut; 6 – plate; 7 – bronze bush, 8 – sealing rings; 9 – dowel; 10 – adjusting nut; 11 – movable support.

The air blow-off valve and its housing are installed on the flange of the combustion chamber rear outer casing so as to enter the engine outer duct with its cylindrical portion. The blow-off valve consists of the following main parts: cylinder 1, rod-and-piston assembly 2, movable support 11, spring 3, plate 6, nut 10 and sealing rings 8.

4. TURBINE
(Fig.14)

The engine turbine is an axial-flow, four-stage, twin-shaft type. The first and second stages of the turbine (the first turbine) impart rotary motion to the rotor of the compressor high-pressure section, whereas the third and forth stages (the second turbine) drive the compressor low-pressure rotor.

The rotors of the first and second turbines spin at different rpm values. Both turbines rotate in the counter-clockwise direction, if viewed from the jet nozzle end. To reduce vibration overloads of the engine casings, the roller bearing of the first turbine and the rear roller bearing of the second turbine are accommodated in resilient damping supports.

(a) First Turbine

The first turbine consists of two nozzle diaphragm assemblies, a roller bearing support and a rotor.

First-Stage Nozzle Diaphragm Assembly
(Fig.14)

The turbine first-stage nozzle diaphragm assembly comprises wheel shroud 16, support 84, 37 vanes 12, and split ring 18.

Axial forces acting on the nozzle diaphragm assembly are transmitted through load-carrying outer shroud 16 and nozzle diaphragm assembly support 84 to the diffuser and the inner casing of the combustion chamber. Circumferential forces are transmitted through the outer shroud to the combustion chamber diffuser.

Nozzle diaphragm assembly support 84 is of a welded construction; it consists of a front tapered portion, an inner ring and front flange 83.

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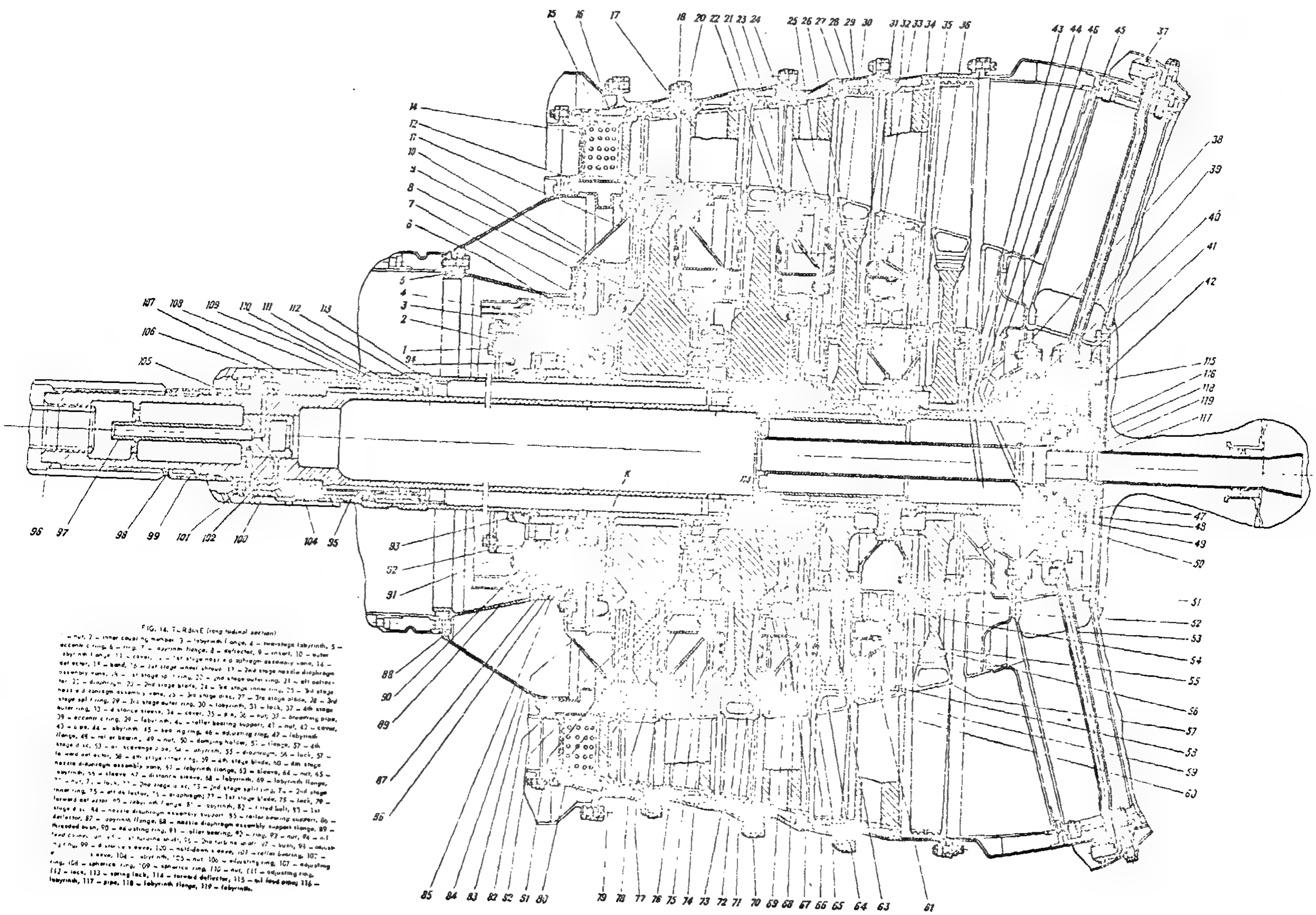

FIG. 14. TURBINE (longitudinal section)

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Nozzle diaphragm assembly vanes 12 are cast to shape. Each vane has flanges at the ends cast integral with the hollow vane airfoil section. The outer flanges of vanes 12 have tapered lugs at the front part and L-shaped lugs at the rear part. The vane lugs are fitted into the respective recesses in load-carrying outer shroud 16. The vanes are secured in shroud 16 by means of dowels to prevent them against axial and circumferential displacement. The flange collars of the inner ends of the vanes are fitted into the circular grooves of the inner ring. There is a clearance between the flanges of adjacent vanes and between the rear ends of the outer flanges of the vanes, which is necessary to allow thermal expansion of the vanes. To ensure uniform and sufficient cooling of the vanes, provision is made for deflectors 14 enclosed inside the vanes. Cooling air is delivered into the spaces between the vanes and the deflectors through 36 holes drilled in load-carrying outer shroud 16 and via 37 holes in band 15.

The front flange of the nozzle diaphragm assembly is bolted with the transition liners of the combustion chamber flame tubes. The middle flange of outer shroud 16 incorporated in the nozzle diaphragm assembly is bolted to the flange of the combustion chamber diffuser.

Split ring 18 consists of 12 sectors and is provided with stiffener ribs on the inside surface. These ribs in conjunction with the ribs on the shroud flanges of first-stage blades 77 form a labyrinth seal reducing the gas flow leaking through the tip clearance.

Second-Stage Nozzle Diaphragm Assembly

The second-stage nozzle diaphragm consists of outer ring 20, split ring 73, inner ring 74, 47 nozzle vanes 17, forward and aft deflectors 79 and 75, diaphragm 76 and labyrinth flange 80.

The circumferential and axial forces acting upon the second-stage nozzle diaphragm assembly are transmitted via the flange of outer ring 20 to the rear flange of the outer ring of the first-stage nozzle diaphragm.

Vane 17 of the second-stage nozzle diaphragm is cast to shape. The hollow airfoil section of the vane is cast integral with the outer and inner flanges.

The nozzle vanes are installed into the respective circular grooves in the outer ring with the use of their L-shaped lugs. The front lug end face of each vane bears against the end face of the ring groove. The vanes are secured by means of radial dowels. There is a clearance between the flanges of adjacent vanes and between the rear ends of the outer flanges of the vanes, which is necessary to allow thermal expansion of the vanes.

The cylindrical bosses on the inner flanges are inserted into the blind holes of inner ring 74, the shoulders on the flanges are installed with an axial clearance onto the circular collars of the inner ring. This method of vane attachment allows free expansion of the rings and vanes in the circumferential, axial and radial directions due to heating during engine operation.

Outer ring 20 is provided with two external flanges. The front flange of the second-stage nozzle diaphragm is bolted to the first-stage nozzle diaphragm assembly. The rear flange is connected with the third-stage nozzle diaphragm assembly. Outer ring 20 has circular grooves receiving the attachment elements of the nozzle vanes.

The aft portion of the outer ring is provided with a circular shoulder and a recess engaging with the lug on split ring 73.

The split ring consisting of 12 sectors is provided with stiffener ribs mating the ribs on the shroud flanges of the second-stage wheel blades to complete the labyrinth seal reducing the gas flow leaks through the tip clearance. Inner ring 74 has two external collars, blind holes (in accordance with the number of the nozzle vanes) and an internal flange.

Roller Bearing Support (Fig.14)

Roller bearing support 85 of the first turbine rotor is a welded structure with a damping element enclosed inside first-stage nozzle diaphragm assembly support 84.

The front flange of roller bearing support 85 is bolted together with nozzle diaphragm assembly support flange 88 and eccentric ring 5 to the inner casing of the combustion chamber. Eccentric ring provides for axial alignment of roller bearing 91 of the first turbine rotor and the bearings of the compressor high-pressure rotor.

Secured to the middle flange of roller bearing support 85 are the shaft tube at the front end face, labyrinth flanges 3 and 87, ring 6 and deflector 86 at the rear end face. Labyrinth flange 7 and labyrinth outer flange 10 are bolted to the rear flange of the roller bearing support.

First Turbine Rotor

The first turbine rotor consists of rotor shaft 95, 1st stage disc 83 carrying eighty blades 77 and deflector 8, 2nd stage disc 72 with eighty-two blades 23, roller bearing 91, the components of the labyrinth seal and fastening parts.

First turbine rotor shaft 95 is hollow; its front end is externally splined, the rear end carrying a flange for attachment of the first-stage and second-stage discs. The splined end of the rotor shaft is coupled to the compressor high-pressure rotor. First turbine rotor shaft 95 is connected to the shaft of the compressor high-pressure rotor by means of hold-down sleeve 100. Probable misalignment of the shafts of the turbine and compressor during operation is compensated for by two spherical rings (108 and 109).

(b) Second Turbine

The second turbine comprises the nozzle diaphragms of the third and fourth turbine stages, a rotor, rear support component parts, labyrinth seals and fastenings.

Third- and Fourth-Stage Nozzle Diaphragm Assemblies

The nozzle diaphragms of the third and forth stages comprise outer rings 29 and 32, 3rd stage split ring 28, inner rings 24 and 58, vanes 25 and 60, forward deflectors 57 and 114, aft deflector 21, diaphragms 22 and 55, and labyrinth flanges 61 and 69.

The third-stage nozzle diaphragm has 65 vanes 25, and the fourth-stage nozzle

diaphragm - 57 vanes 60. The flow path in the nozzle diaphragms is formed by vane outer and inner flanges cast integral with the vane hollow airfoil sections.

The axial and circumferential forces acting on the nozzle diaphragms of the third and fourth turbine stages are transferred to the rear flange of the second-stage nozzle diaphragm assembly via the flanges of outer rings 29 and 32.

The rear flange of outer ring 32 incorporated in the fourth-stage nozzle diaphragm bolts the second turbine rear support. The nozzle diaphragms of the third and fourth stages are similar to that of the turbine second stage in construction.

Second Turbine Rotor

The second turbine rotor comprises shaft 96, 3rd stage disc 26 carrying 81 moving blades 27, 4th stage disc 52 with 73 moving blades 59, front roller bearing 101, rear roller bearing 48, labyrinth seal component parts, components serving for oil supply to the front roller bearing, distance sleeves, and the nuts for attachment of the turbine bearings and discs.

Second turbine shaft 96 is hollow. It is arranged concentrically inside the shaft of the first turbine rotor; it rides on front roller bearing 101 and rear roller bearing 48. The external splines in the shaft front end couple the latter to the intermediate shaft of the compressor low-pressure section; the shaft is secured in the axial direction by a coupling bolt screwed into the internal threads provided in the shaft front end.

The shaft is flanged at the rear end to mount the third-stage disc in front of the flange by means of axial fitted pins 35. The disc is guarded against axial displacement with the help of nut 70 holding also distance sleeve 33 and labyrinths 30 and 65. Fourth-stage disc 52 is mounted on the same fitted pins at the rear face of the flange. The disc is held by nut 36.

Rear Support

The damper rear support consists of labyrinth flange 47, roller bearing support 40, damping holder 50, cover 42, eccentric ring 38, breathing pipe 37, oil scavenge pipe 53, oil feed pipe 115, labyrinths 116 and 119 and pipe 117.

Labyrinth flange 47 mating with labyrinths 39 and 44 forms an air seal.

Support 40 and holder 50 are provided with resilient two-sided damping elements of the "squirrel-cage" type. Oil is supplied into the clearance between the support and holder and is sealed by two pairs of oil sealing rings. Eccentric ring 38 provides for axial alignment of roller bearing 48 of the second turbine rotor and the bearings of the first turbine rotor.

The cover central flange bolts labyrinths 116 and 119 and pipe 117 designed for sealing air in and bleeding it from cavity K into the jet nozzle space.

5. EXHAUST NOZZLE SECTION
(Fig.15)

The engine is furnished with a jet nozzle, the purpose of which is to mix the flows of air and gases discharged from the by-pass and main ducts respectively and to turn the exhaust gas stream by 3 or 4 deg. outward in the horizontal plane.

The exhaust jet nozzle section structurally incorporates the rear support of the second turbine.

The exhaust nozzle consists of the following main units: a casing, a final jet nozzle, a rear support, a mixer and an inner cone.

C a s i n g 24 is of a welded construction. It comprises a conical shroud, forward 1 and aft 36 flanges. The forward flange on the casing bolts to the aft flange of the combustion chamber rear casing, the rear flange of the casing carrying flange 38 of the final jet nozzle.

Welded to the casing top portion over the outside contour of segmental slots A made in aft flange 36 is duct shroud 23 which forms channel K in conjunction with casing 24. Duct shroud 23 carries welded flange 20 that bolts a breathing pipeline. Drain tank 18 is seam-welded to the casing bottom portion.

A hollow is made in the casing vertical plane, where the drain tank is welded, to form the lowermost area of the engine by-pass duct and collect fuel accumulating in the by-pass duct. The fuel is drained into drain tank 18 through a hole drilled in the hollow.

Fuel accumulated in the drain tank is forced under the air pressure through pipe connection 19 and is then piped to the breathing pipeline.

The forward right-hand part of the casing has hole B with concentrically welded cover plate 52 and flange 53 which are intended for attachment of pressure pick-up for measuring turbine outlet total pressure.

T h e f i n a l j e t n o z z l e is of a welded construction consisting of flange 38, adapter 40 and ring 50. The adapter and the ring form a curved convergent duct, the purpose of which is to confine the exhaust gases to a given area, thereby accelerating them, and to turn the mixed flow in the horizontal plane by an angle of 3 to 4 deg. relative to the engine longitudinal axis.

The jet nozzle outer surface carries two shrouds 39 welded over segmental slots B in flange 38. One of the shrouds is an extension of duct shroud 23 made over casing 24.

The breathing pipeline is connected to the outlet at the final nozzle edge via duct 23 on casing 24 and shroud 39 on the final nozzle.

Rear Support
(Fig.15)

Incorporated in the rear support structure are the following main units: a rear support outer casing, baffles, an inner shroud, a rear support housing, fairings, a diaphragm, a machined housing and thermocouple housing.

(a) T h e w e l d e d r e a r s u p p o r t o u t e r c a s i n g comprises shroud 26, forward flange 2 and aft flange 27. The external surface of the rear support outer casing forms the inner wall of the by-pass flow path in the section between the turbine and mixer 41.

Forward flange 2 of the rear support outer casing is bolted to the rear flange of the outer casing of the turbine forth-stage nozzle diaphragm, aft flange 27 carrying mixer 41. Shroud 26 has eight equispaced oval holes provided with seam-welded flanges 25 which are used to attach the rear support housing. Hole Л is made in the shroud at the right for installation of a pick-up measuring total pressure downstream of the turbine.

Rear support flanges 25 are provided with baffles 22 serving to introduce air from the by-pass duct for cooling the thermocouple manifold, the second turbine rear

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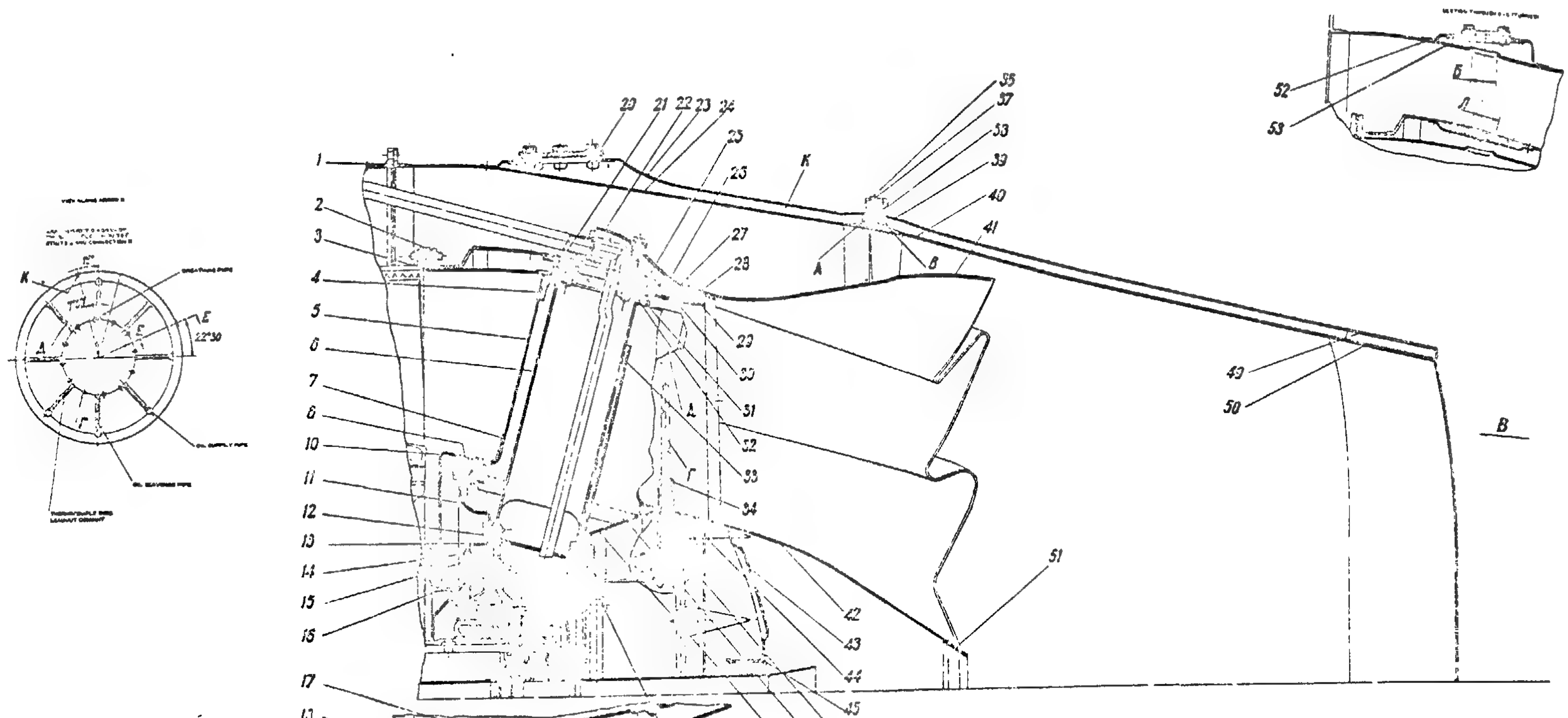

FIG. 15. FLOW MIXING JET NOZZLE (longitudinal section)

1 — casing forward flange; 2 — rear support housing forward flange; 3 — inner shroud; 4, 7 — fairing cover strip; 5 — fairing; 6 — rear support housing strut; 8 — fairing flue gas; 10 — ring; 11 — outer diaphragm; 12 — rear support housing forward flange; 13 — housing; 14 — rivet; 15 — cover strip; 16 — inner diaphragm; 17 — baffle; 18 — drain collecting reservoir; 19 — pipe connection; 20 — pipe connection flange; 21 — [illegible] cover plate; 22 — boss; 23 — dust; 24 — casing; 25 — rear support housing flange; 26 — rear support housing [illegible]; 27 — [illegible] housing aft flange; 28 — mixer flange; 29 — inner shroud cover strip; 30 — inner shroud flange; 31 — cover; 32 — rear support housing flange; 33 — fairing Г-shaped ribs; 34 — thermocouple bracket; 35 — rear support housing aft flange; 36 — casing aft flange; 37 — gasket; 38 — jet nozzle flange; 39 — jet nozzle shroud; 40 — sleeve; 41 — mixer; 42 — rear cone taper sheet; 43 — deflector; 44 — rear cone flange; 45 — sleeve; 46 — thermocouple housing rear flange; 47 — forward cone; 48 — thermocouple housing front flange; 49 — jet nozzle shroud cover ring; 50 — final nozzle ring; 51 — rear cone aft ring; 52 — cover plate; 53 — flange.

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25X1

support component parts, the forth-stage disc, and for pressurizing the rear support labyrinth seals.

(b) The welded inner shroud comprises shroud 3, flange 30 and cover strip 29. The inner shroud forms the outer wall of the engine main duct downstream of the turbine and protects titanium rear support outer shroud 26 against overheating.

Shroud 3 has eight oval holes for connection of flanges 25 and 32 of the rear support housings.

(c) The rear support housing is of a welded construction. It comprises eight stamped hollow struts 6, two circular flanges 12 and 35, and eight flanges 32. Rear support housing flanges 32 bolt flanges 25 of rear support outer shroud 26. Forward flange 12 carries diaphragm 11. Attached to aft flange 35 are housing 13, fairings 5 provided with П-shaped ribs, and a thermocouple housing.

(d) Fairings 5 are attached to the rear support housing to protect the stay struts against overheating by the gas flow. The fairings are made of stamped sections welded together to form streamlined struts. The latter are provided with conical flanges forming the inner wall of the duct downstream of the engine turbine.

(e) The diaphragm consists of two parts: stamped outer diaphragm 11 and turned inner diaphragm 16. The diaphragm separates the interior cavities of the rear support housing from the engine gas flow path.

(f) Housing 13 is turned to shape. The outer forward and aft flanges of the housing are bolted to rear support housing flanges 12 and 35 respectively.

Attached to the forward inner flange of housing 13 are the support and seal components of the turbine rear roller bearing unit; the aft flange of housing 13 carries fairings 5 and thermocouple housing front flange 48.

(g) The thermocouple housing is welded of flanges 46 and 48 and forward cone 47. Flange 48 of the thermocouple housing is bolted to rear support housing aft flange 35. The front wall of the housing has holes for passing air from the outer duct for cooling the thermocouple manifold and turbine parts. The holes are drilled between the thermocouple housing attachment holes. Four holes in flange 48 are used to pass the bolts for attachment of the clamps securing the thermocouple manifold. The taper surface of flange 46 is provided with twelve radial drillings for installation of thermocouple brackets 34. Each thermocouple bracket is attached to the end face of flange 46 by means of two bolts. Thermocouples Г are installed in the brackets and secured by means of bolts.

Mixer
(Fig.15)

The mixer is an exhaust nozzle element intended for mixing the air and gas flows running out of the by-pass and main ducts of the engine.

Mixer 41 is welded of twelve stamped flaps and flange 28. Flange 28 is used to locate and attach the mixer to aft flange 27 of rear support outer shroud 26.

The welded inner cone comprises taper shell 42, flange 44, deflector 43 and sleeve 45. The cone outer surface and the surfaces of ring 10 and fairings 5 make up the flow path downstream of the engine turbine.

6. ENGINE AIR AND DEICING SYSTEMS
(Fig.16)

(a) Air System

The engine employs a number of auxiliary air lines by means of which air is bled from the by-pass and main ducts for certain engine and aircraft needs. Compressed air is used for pressurizing the labyrinth seals of the oil-contacted cavities of all the bearings supporting the compressor and turbine rotors and the bearings incorporated in the drives of the starter-generators and tachometer generators of both rotors.

To cool the turbine parts, the air is bled from the main (high-pressure) and by-pass (low-pressure) ducts of the engine. High-pressure air is used for cooling the first-stage nozzle diaphragm vanes and moving blades as well as the discs of the turbine first three stages (from both sides). Low-pressure air cools both sides of the forth-stage disc, the outer rings of all the nozzle diaphragm assemblies and the component parts of the low-pressure turbine rear support.

The automatic starting fuel control unit incorporated in fuel-regulating pump НР-30 is fed with high-pressure air supplied from the compressor high-pressure section through pipeline 19 and air filter 20.

To pressurize and purge drain tank 25, low-pressure air is fed along pipeline 23. Additional drain tank 18 is pressurized and purged with low-pressure air ducted through the hole in the exhaust nozzle casing.

The ejector of ice detector ДО-202В is fed with low-pressure air delivered from special intake 24 in the by-pass duct entry housing flow path.

The aircraft passenger cabins are pressurized and vented with air bled from the blow-off unit housing aft of the fourth stage of the compressor low-pressure section through one of two air bleed ducts 8 or 22. The deicing system of the aircraft wing and fin receives air bled from the blow-off unit housing aft of the compressor fifth stage through one of two air bleed ducts 9 or 21. The air intake is heated by high-pressure air supplied via pipeline 12 at a speed of the compressor high-pressure rotor exceeding 9400 rpm or via pipeline 16 at a high-pressure rotor speed below 9400 rpm. Change-over of the air bleed system is accomplished automatically by means of butterfly valve 13, controlled by a hydraulic actuator. The hydraulic actuator is supplied with fuel from fuel-regulating pump НР-30 via centrifugal speed governor ЦР-2В.

To improve engine starting characteristics, the compressor high-pressure section has provisions for by-passing air from the tenth stage of the h.p. compressor section via valve 17. The valve is closed automatically by the action of pressure difference in the main and by-pass ducts of the engine, built-up at the compressor high-pressure rotor speed within 6000 ± 250 rpm.

The aircraft hydraulic tank is pressurized with high-pressure air supplied from the compressor high-pressure section through pipeline 14. The aircraft fuel tanks are pressurized with low-pressure air delivered via pipe connection 5.

(b) Deicing System

To heat low-pressure compressor inlet guide vanes 2 and nose bullet 1, provision is made for a deicing system.

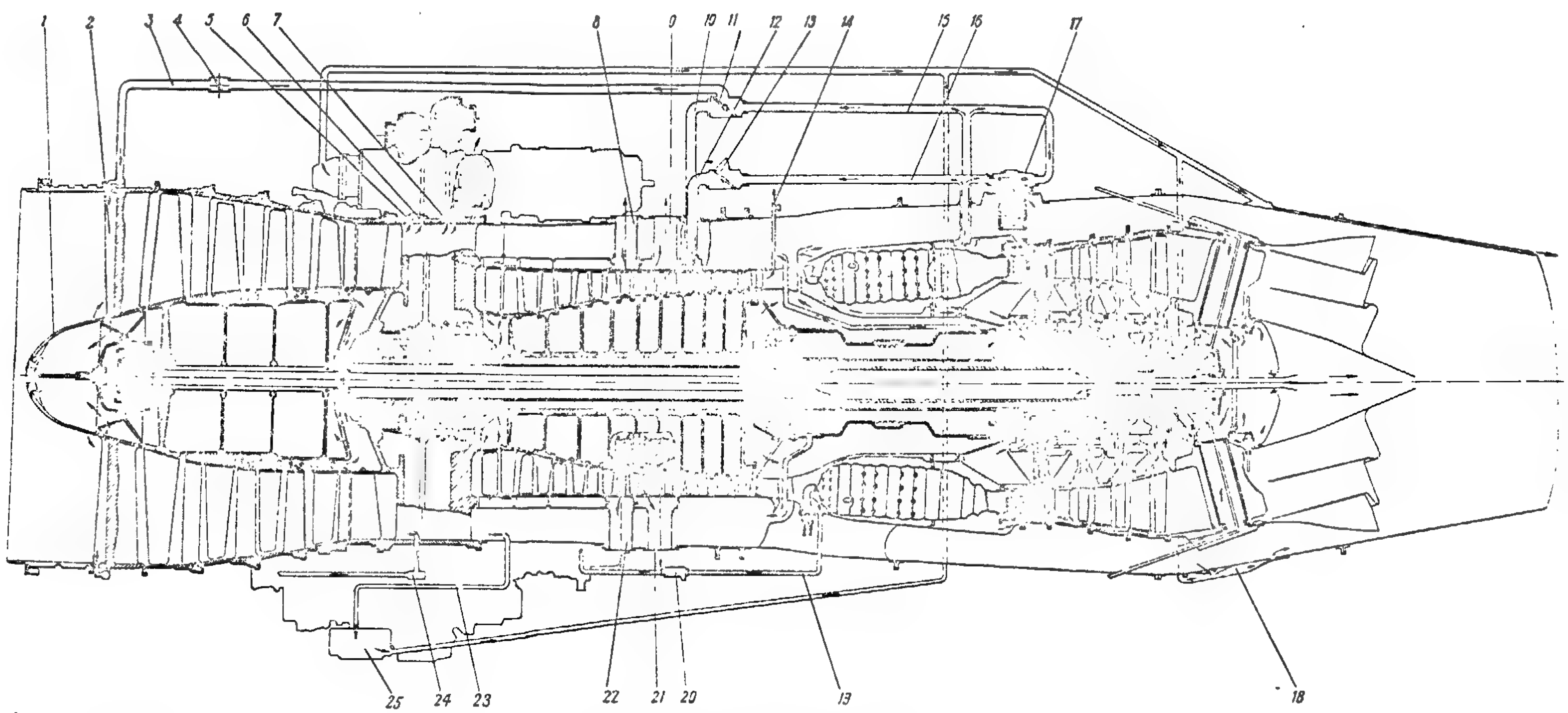

FIG. 16. ENGINE AIR AND DEICING SYSTEMS

1 – engine nose bullet; 2 – low-pressure compressor inlet guide vanes; 3 – engine deicing system heat-insulated pipeline; 4 – shut-off valve; 5 – vacant pipe connection located on by-pass duct entry housing; 6 – hole for pressurization of oil sealing labyrinth incorporated in l.p. compressor rotor speed tachometer generator drive; 7 – hole for pressurization of oil sealing labyrinth incorporated in h.p. compressor rotor speed tachometer generator drive; 8, 22 – air bleed ducts supplying air for pressurization of aircraft passenger cabin; 9, 21 – air bleed ducts supplying air to aircraft wing and fin deicing systems; 10 – compressor 5th stage air bleed pipeline employed for supplying compressed air to engine deicing system; 11, 13 – butterfly valves; 12 – air bleed pipeline used for supplying compressed air into aircraft air intake at compressor h.p. section speed exceeding 9400 rpm; 14 – air bleed pipeline supplying air for pressurization of aircraft hydraulic tank; 15 – pipeline for bleeding air aft of compressor h.p. section 10th stage to engine deicing system; 16 – pipeline used for bleeding air and supplying it into aircraft air intake heating system at compressor h.p. section rotor speed below 9400 rpm; 17 – [illegible] by-passing compressed air into by-pass duct; 18 – additional drain tank; 19 – pipeline supplying compressor discharge air to starting control unit of fuel regulating pump HP-30; 20 – air filter; 23 – drain tank pressurization pipeline; 24 – pipeline supplying compressed air to ejector of ice detector [illegible]; 25 – drain tank.

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The system comprises pipeline 15 used for bleeding air from the compressor high-pressure section, compressor 5th stage air bleed pipeline 10, butterfly valve 11 used for changing-over air supply (controlled by a hydraulic actuator), heat-insulated pipeline 3, shut-off valve 4 (provided with an electric actuator) and ice warning system units.

The change-over of air bleed either from the fifth of tenth stage of the compressor high-pressure section is effected automatically by supplying high-pressure fuel from fuel regulating pump НР-30 via centrifugal governor ЦР-2В to the hydraulic actuator. Shut-off valve 4 gets open automatically under the action of electric actuator МП-5М as soon as the latter receives a signal from ice detector ДО-202М. The electric actuator may be operated manually as well.

The ice warning system is designed for automatic control of shut-off valve 4. The system (Fig.17) comprises ДО-202М ice detector 1, solenoid-operated valve 2, pressure switch 3 and air intake probe 4 supplying air into the ice detector ejector.

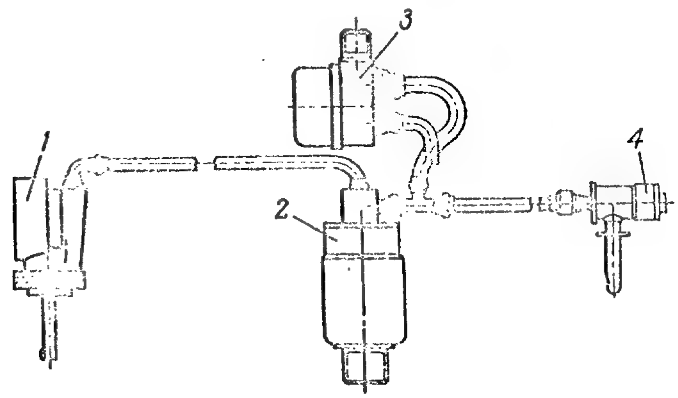

FIG. 17. ICE WARNING SYSTEM

1 – ice detector ДО-202М; 2 – valve М762000; 3 – pressure switch СДУ2-0,15; 4 – air intake probe supplying compressor low-pressure discharge air to ejector of ice detector ДО-202М.

The purpose of ice detector ДО-202М is to warn on ice formation in the engine air inlet duct. The functional diagram of the detector is presented in Fig.18. Electric mechanism МП-5М starts opening shut-off valve 4, and the ice warning light comes on, as soon as contacts 7 of the pressure differential gauge get closed. The contacts close after ice detector tip orifices 1 get clogged with ice and the air pressures acting upon one and the reverse sides of membrane 6 equalize due to low ram pressure sensed by the detector probe.

Pressure differential is built up in the gauge (up to n_2 = 8400 rpm) due to reduction of air pressure in chamber 3 under the action of ejector 5. Solenoid-operated valve 2 (Fig.17) serves for control of air supply into the ejector from the compressor low-pressure section. Pressure switch СДУ2-0,15 breakes the circuit of valve 2 as soon as the surplus pressure downstream of the low-pressure section is above 0.15 kg/sq.cm. As a result, air supply to the ejector is cut off.

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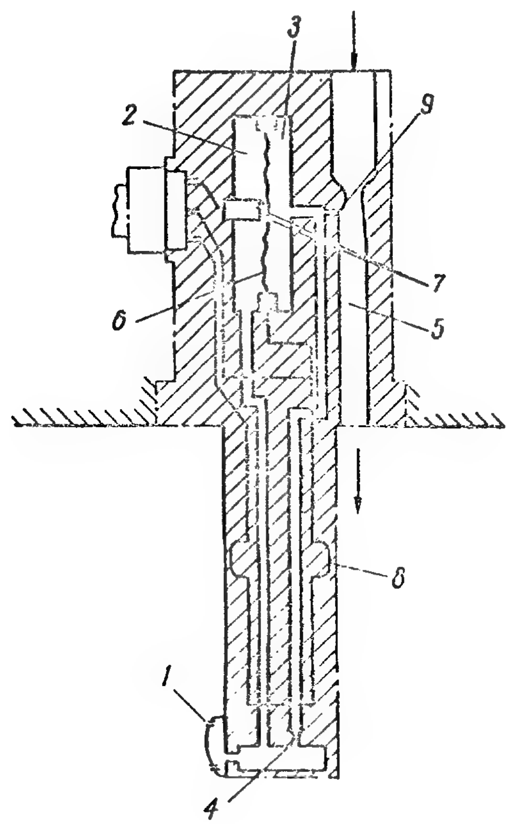

FIG. 13. ДО-202М ICE DETECTOR FUNCTIONAL DIAGRAM

1 – Ice detector tip orifices; 2 – total pressure chamber; 3 – static pressure chamber; 4 – orifice (jet); 5 – ejector; 6 – membrane; 7 – contacts; 8 – heater; 9 – opening interconnecting ejector cavity and static pressure chamber.

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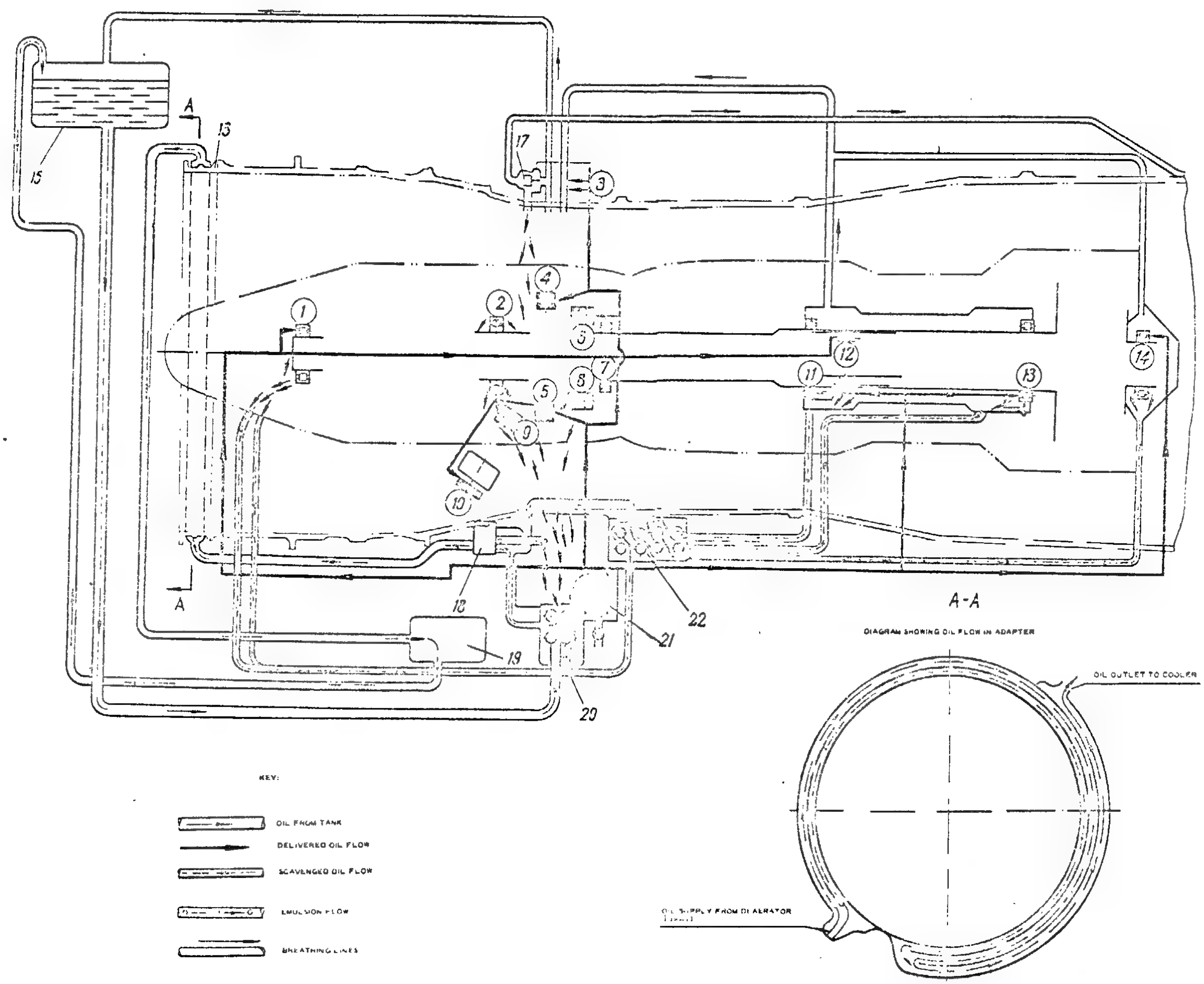

FIG. 16. ENGINE LUBRICATING OIL AND BREATHING SYSTEM

1, 2, 7, 11, 12, 13, 14 = oil supply to engine load-carrying bearings; 3 = oil supply to upper drive gear box bearings, 4 = oil supply to driving gear bearings of upper drive gear box; 5 = oil supply to driving gear bearings of lower drive gear box; 6, 8 = oil supply to central drive bearings; 9 = oil supply to drive shaft bearings of righthand drive gear box; 10 = oil supply to bearings of righthand drive gear box; 15 = oil tank; 1[illegible] = centrifugal breather [illegible]; 18 = centrifugal deaerator [illegible] with [illegible] scavenged oil strainer (unit 62); 20 = main oil pump [illegible]; 21 = oil filter [illegible] scavenging pump [illegible].

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7. ENGINE LUBRICATING OIL AND BREATHING SYSTEMS (Fig.19)

The engine lubricating oil and breathing systems comprise the following assemblies and units: oil tank, main oil pump ОМН-30, gauze oil filter МФС-30, oil scavenging pump МНО-30, centrifugal deaerator МВО-ЦС-30 with a chip-detecting filter, centrifugal breather ЦС-30, inlet housing adapter, employed for cooling oil, and fuel-cooled oil cooler (unit 62).

The lubricating oil system ensures constant oil flow to the bearings and the friction surfaces of the components during engine operation, in order to reduce friction and dissipate generated heat. While the engine is running, oil from the oil tank arranged on the aircraft is drawn by main oil pump ОМН-30 and is delivered to gauze oil filter МФС-30. After passing the filter, the oil is carried in four directions:

1. Along the internal passages in the by-pass duct entry housing, in the accessory drive housing, and in the gear box housings oil is supplied to the bearings and the gears of the central drive and the drive gear boxes, as well as to the compressor low-pressure rotor ball bearing and the compressor high-pressure rotor roller bearing.

2. Via an external pipe oil is delivered to the compressor low-pressure section front frame and flows to the compressor low-pressure rotor roller bearing and to the second turbine front roller bearing.

3. Along another external pipe oil is carried to the shaft tube for lubrication of the first turbine rotor roller bearing and compressor high-pressure rotor ball bearing.

4. Along another external pipe oil is brought to the second turbine rotor rear support for lubrication of the second turbine roller bearing.

Oil flow scavenged from the compressor front frame cavities, from the shaft tube and turbine rear support by oil scavenging pump МНО-30 and oil flow drawn from the cavities of the by-pass duct entry housing and the lower accessory drive gear box by the scavenging element of main oil pump ОМН-30 are supplied into the compressor front frame adapter via centrifugal deaerator МВО-ЦС-30.

After passing through the front frame adapter, partially cooled oil flows through the fuel-cooled oil cooler and enters the oil tank. Air or oil emulsion separated in the centrifugal deaerator is carried via the ball-type emulsion valves into the compressor by-pass duct entry housing.

To provide for normal operation of the lubricating oil system, the interior spaces of the by-pass duct entry housing, the shaft tube, the turbine rear support and the oil tank communicate with the atmosphere via the centrifugal breather. The breathing line is brought to the final nozzle edge via an external pipeline.

The centrifugal breather maintains a certain surplus pressure in the engine oil-contacted cavities and in the oil tank, due to which back pressure is built up at the inlet to the pressure and scavenging elements of the oil pumps.

Oil pressure in the engine lubricating oil system is measured downstream of the delivery element of main oil pump ОМН-30 (aft of the filter) by transmitter ИМТ-8 (series III), which is a part of the ЭМИ-3РТИ set, mounted on the measuring instrument board.

Temperature of oil at the inlet to the delivery element of the oil pump is checked by thermometer П-63 (incorporated in the ЭМИ-3РТИ set), whose sensor is installed in the lower drive gear box.

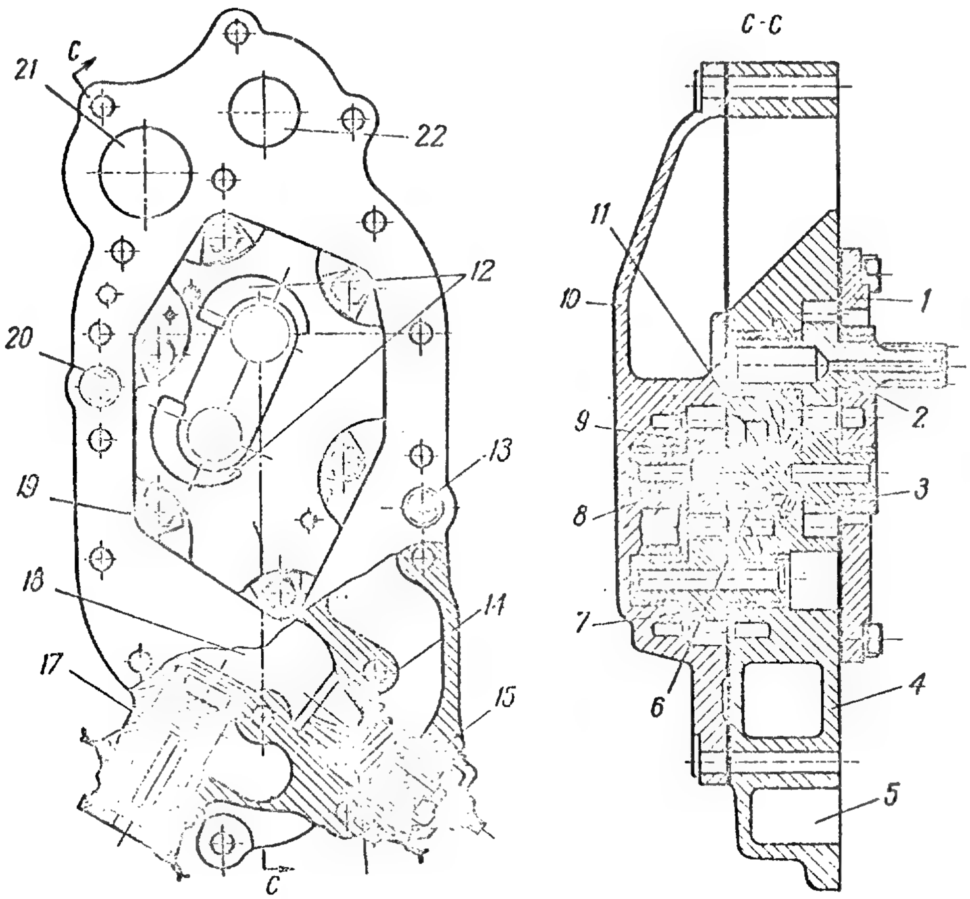


FIG. 20. MAIN OIL PUMP OMH-30

1 – upper cover; 2, 3 – scavenging element gears; 4 – housing; 5 – delivery element oil outlet passage; 6 – spring; 7, 9 – delivery element gears; 8 – spherical sling; 10 – lower cover; 11 – bushing; 12 – scavenging element oil inlet passages, 13, 20 – screws, 14 – pressure control valve; 15 – pressure control valve adjusting screw; 16 – spring; 17 – non-return valve; 18 – valve accommodating cavity; 19 – bolt; 21 – delivery element oil inlet passage; 22 – scavenging element oil outlet passage.

The purpose of main oil pump CMH-30 (Fig.20) is to supply oil under pressure to the engine components to be lubricated and for scavenging oil drained into the lower drive gear box from the by-pass duct entry housing and from the other drive gear boxes.

The main oil pump is of a gear type; it consists of a pressure and scavenging elements. Housing 4 and covers 1 and 10 of the oil pump are cast of magnesium alloy. Accommodated in the oil pump housing are pressure control valve 14 and non-return valve 17.

The pressure control valve is designed for adjusting pressure of oil delivered by the oil pump into the engine oil lines. As soon as the pressure in the engine oil lines comes to exceed the preset value, the pressure control valve by-passes part of the oil into the inlet of the delivery element of the pump. Oil pressure is adjusted by turning screw 15 with a resultant change in pressure of spring 16 on valve 14.

Non-return valve 17 serves to preclude oil flow from the lube oil tank into the engine, with the aircraft parked. The non-return valve allows oil flow into the engine as soon as oil pressure upstream of the valve comes up to 0.4 or 0.6 kg/sq.cm. For the sake of convenience in removal and installation of the non-return valve, it is made as a separate unit.

Oil scavenging pump MHO-30 (Fig.21) is designed for scavenging oil from the shaft tube, from the compressor front frame and from the turbine rear support.

The oil pump is of a gear type; it consists of four scavenging elements. Oil to the gears of the scavenging elements flows in the radial direction. To enhance the scavenging effect of the pump, all its four elements are made with very small side clearances.

Housings 4, 9 and 10 and covers 3 and 11 are cast of magnesium alloy. The flanges of housing 9 and rear cover 3 of the pump are provided with pipe connections 1, 24 and 25 for receiving oil scavenged from the shaft tube cavities by the second and third elements, and oil scavenged from the turbine rear support cavities by the first scavenging element of the pump. The fourth scavenging element handles oil supplyed via passage 26 of front cover 11 and taken from the front frame cavity along a pipeline and a passage in the lower drive gear box. From all the scavenging elements of the pump oil flows via passage 27 of the pump, passes through a channel in the lower drive gear box and enters centrifugal deaerator ЦВО-СС-30.

The centrifugal deaerator (Fig.22) provided with a chip-detecting filter is designed for separation of air from oil scavenged from the engine by oil scavenging pump MHO-30 and by the scavenging element of main oil pump CMH-30. It serves also to send a signal warning on detection of chips in the engine lubricating oil system.

The housing of the chip-detecting filter is installed on the centrifugal deaerator housing.

The ЦВО-СС-30 unit consists of three housing sections 14, 15 and 26, rotor 24, shaft 23, emulsion ball valves 22, chip-detecting filter 10 and by-pass valve 11.

Housings 14, 15 and 26 are cast of magnesium alloy. Oil from oil scavenging pump CMH-30 and from the scavenging element of main oil pump CMH-30 flows into deaerator inlet chamber 21 of housing 26 to be conducted further into the annular chamber of deaerator rotor 24. The centrifugal forces throw the heavier oil particles to the periphery of the rotor inner space to bring the separated oil into cavity 16 of volute housing 15 via circular space 18. More light air and oil vapour parti-

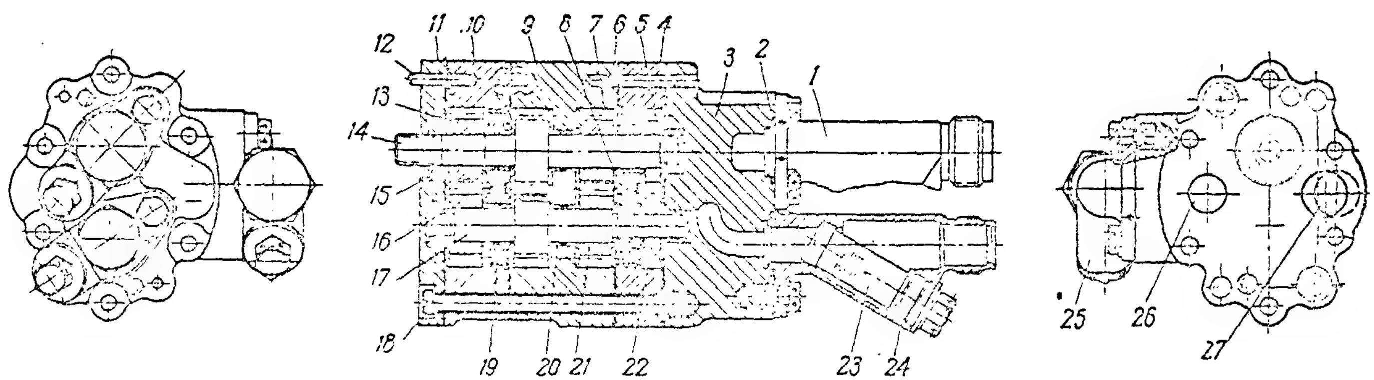


FIG. 21. OIL SCAVENGING PUMP MHO-30

1, 24, 25 – connections; 2 – sealing ring, 3, 11 – covers; 4, 9, 10 – oil pump housings; 5, 22 – gears of pump element scavenging oil from second turbine rear roller bearing void, 6, 12 – dowel pins; 7, 21 – gears of pump element scavenging oil from compressor high-pressure rotor ball bearing void; 8 – washer, 13, 16 – gears of pump element scavenging oil from compressor low-pressure rotor roller bearing void; 14, 17 – driving and driven shafts with gears of pump element scavenging oil from first turbine roller bearing void; 15 – sealing ring; 18 – bolt; 19 – spring; 20 – bushing; 23 – gauze filter; 26 – passage leading to pump element scavenging oil from compressor low-pressure rotor roller bearing void, 27 – scavenging pump oil outlet.

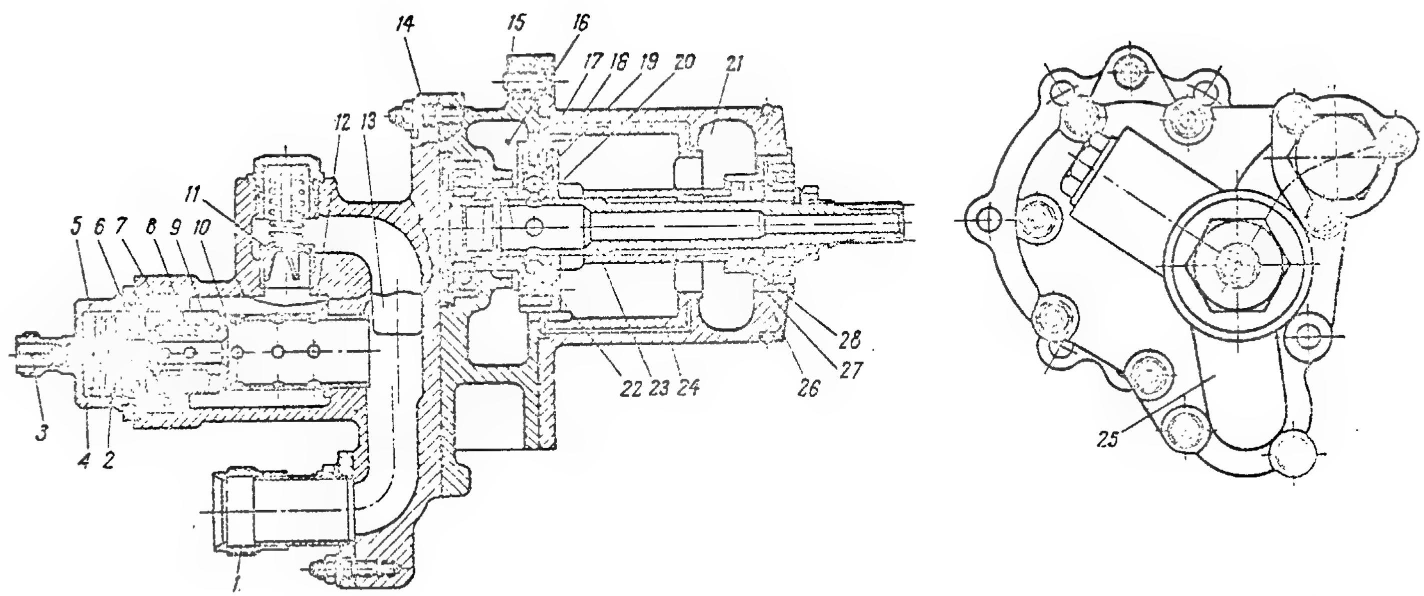


FIG. 22. CENTRIFUGAL DEAERATOR UBO-ФC-30

1 – pipe connection; 2 – spring, 3 – contact; 4 – cover plug; 5 – plunger; 6, 7 – bushes; 8 – discs; 9 – stem; 10 – chip-detecting filter; 11 – by-pass valve; 12 – filter chamber; 13 – centrifugal deaerator oil outlet passage; 14, 15, 26 – housing sections; 16 – deaerator volute cavity; 17 – sleeve; 18 – deaerator circular space; 19 – spring; 20 – hole designed for conveying emulsion from rotor space into shaft interior cavity; 21 – deaerator inlet chamber; 22 – emulsion ball valves; 23 – shaft; 24 – rotor; 25 – passage for oil supply into filter chamber; 27 – oil sealing bush; 28 – ring.

cles accumulate in the centre of the rotor hollow and are carried through holes 20 into the shaft hollow space and further into the interior space of the lower drive gear box, with the ball-type emulsion valves open.

From deaerator housing 15 oil flows into housing 14 and after passing through the chip-detecting filter is carried from the deaerator into the front frame adapter. When oil contaminated with metal particles flows through the discs of the filter, the convergent passages and inter-disc slots get clogged with the particles, thereby closing the circuit. As a result, an indicating light comes on indicating that the lubricating oil is contaminated with metal particles. The indicating light flashes up only in case all the twenty discs of the chip-detecting filter make up a closed circuit.

In case the gauze and slots between filter discs 8 get blocked with dirt or some other particles, oil pressure in chamber 12 rises, by-pass valve 11 opens, and oil is carried from the deaerator via passage 13, by-passing the chip-detecting filter.

The centrifugal breather (Fig.23) serves for separating oil vapours from the emulsion carried to the breather via the external breathing pipes and the passage provided in the upper drive gear box from the oil space of the by-pass duct entry housing, from the shaft tube, from the turbine rear support and from the oil tank.

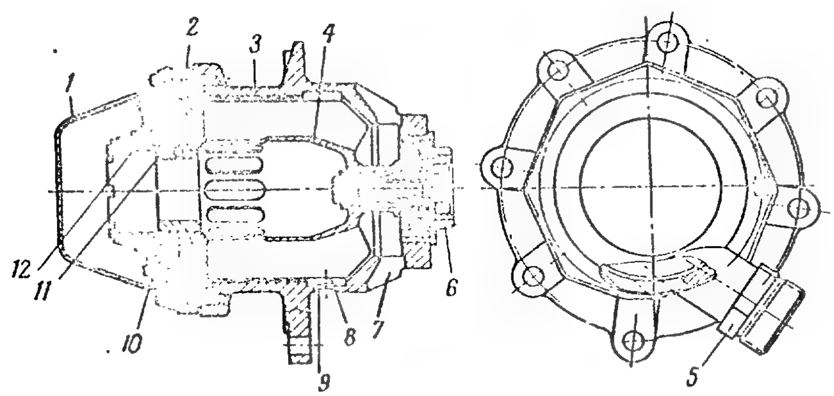


FIG. 23. CENTRIFUGAL BREATHER ПС-30

1 – casing; 2 – cover; 3 – housing; 4 – impeller; 5 – outlet connection; 6 – gear; 7 – ports for air supply to breather impeller; 8 – recess in breather housing; 9 – decerated oil drain port communicating with upper drive gear box; 10 – sleeve; 11 – bush; 12 – ring.

The centrifugal breather consists of housing 3, cover 2, casing 1, and impeller 4 mounted inside the housing on two bearings. Housing 3 is cast of magnesium alloy.

Air saturated with oil vapour enters the impeller interblade space via four ports 7 cut in the centrifugal breather housing. More heavy oil particles are thrown by the centrifugal forces to the peripheral surface of the housing provided with an oil-slinging ten-start spiral grooves. Oil flows along the spiral grooves and enters internal circular recess 8 in the housing, whence it is drained into the upper drive gear box via port 9 in the centrifugal breather housing.

The air cleaned of oil is carried via the ports in the impeller and bush 11 inside casing 1, whence it is scavenged into the atmosphere via pipe connection 5 and the external breathing pipe running to the edge of the engine by-pass duct exhaust unit.

The centrifugal breather maintains surplus pressure in the oil spaces and in the oil tank.

Oil filter МФС-30 (Fig.24) is designed for filtering oil entering the engine from the delivery element of main oil pump ОМН-30. The filter consists of cover 11, cylindrical hollow carcass 6, filtering elements 2, plug 12 with tommy bar 13, and safety valve 8 mounted in the filter cover.

The filter cover is cast of aluminium alloy; the filter carcass and the bush with the tommy bar are made of steel, whereas the gauzes of the filtering elements are manufactured from brass.

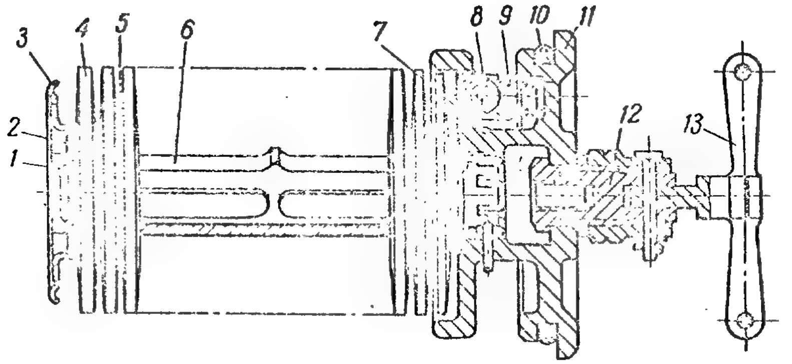


FIG. 24. OIL FILTER МФС-30
1 – sealing ring; 2, 4 – filtering elements; 3 – protective washer; 5 – gasket; 6 – carcass; 7 – locking ring; 8 – safety valve; 9 – spring; 10 – sealing ring; 11 – cover; 12 – plug; 13 – tommy bar.

Oil from the delivery element of main oil pump ОМН-30 flows into the filter housing, passes through the gauzes of the filtering elements to get into the inner space and further flows along the passages in the cover and the filter housing to be delivered into the engine.

The filter cover accommodates safety ball-type valve 8 by-passing oil directly into the engine, when the filtering elements get clogged. The valve opens as soon as oil pressure differential across the filter comes to amount to 0.7 – 1.4 kg/sq.cm.

8. ENGINE FUEL SYSTEM AND AUTOMATIC CONTROL UNITS (Fig.25)

The engine fuel system is comprised of a low-pressure system, a high-pressure system, and a drain system.

The low-pressure system incorporates the following units: fuel tank 1, aircraft fuel booster pump 2, booster pump ДЦН-44-П3Т 3, flowmeter 6, fuel-cooled oil cooler

20 (unit 62), fuel gauze filter 21 retaining particles larger than 20 microns, and pipelines connecting the above units.

The high-pressure system includes: HP-30 fuel regulating pump 37, HP-2B centrifugal governor 25, HP-1B centrifugal governor 29, hydraulic actuators 12 controlling air blow-off shutters aft of compressor high-pressure stages IV and V, hydraulic actuators 14 controlling air bleed butterfly valves aft of 5th and 10th stages of the compressor high-pressure section, hydraulic cylinder 7 controlling the position of the inlet guide vanes, fuel filters 8 and 18, small-slot and large-slot fuel manifolds 41 and 42, 12 fuel burners, and pipelines connecting the above units.

The drain system includes the following units: main drain tank 16 secured to the lower drive gear box, the drain sump of exhaust unit, and pipelines connecting the drain spaces of the fuel system units with the drain tank. From the drain tank and the exhaust unit drain sump fuel is forced by the air via individual pipes and breathing pipeline to the edge of the final nozzle.

From tank 1 fuel is delivered by aircraft booster pump 2 via a pipeline to ДЦН-44-П3Т fuel booster pump 3. From this booster pump fuel enters HP-30 fuel regulating pump 37 via flowmeter 6, fuel-cooled oil cooler 20 and filter 21. From the fuel regulating pump fuel under pressure is supplied into primary and main circular manifolds 41 and 42 to be sprayed into the combustion chamber flame tubes via 12 fuel burners CP-30KC.

Pipe connection 47 of fuel manifold 41 is intended for measuring fuel pressure in the small-slot manifold. It is connected to transmitter ИДТ-100 (series III) via snubber Д59-2.

High-pressure fuel upstream of the throttle valve of fuel regulating pump HP-30 is bled into HP-2B centrifugal governor 25 to be further carried to hydraulic actuators 12, 14 and 7 via filters 8 and 18. Pipeline 32 connects centrifugal governor HP-1B with the hydraulic decelerator cavity accommodated in the HP-30 fuel regulating pump.

Pipe connection 34 of centrifugal governor HP-1B is connected to transmitter ИДТ-4 (series III) via snubber Д59-4. The purpose of the transmitter is to measure fuel pressure at the inlet to fuel regulating pump HP-30. Pipelines 39 and 28 provided with air cleaner 40 are used to deliver air tapped from the compressor high-pressure section to the starting fuel control unit incorporated in the fuel regulating pump.

The air filter is provided with a pressure relief valve adjusted to an opening pressure of within $3^{+0.3}$ kg/sq.cm which is the pressure limit in the membrane chamber of the starting fuel control unit incorporated in the fuel regulating pump.

The fuel regulating pump constitutes the main unit of the engine fuel supply system; it provides for pumping and automatic regulation of the fuel flow fed into the engine at any operating conditions, including acceleration and starting (Fig.26). Fuel regulating pump HP-30 comprises the following main units:

(a) high-pressure pump 78 (pumping unit) serving for supply of high-pressure fuel into the burners installed in the engine combustion chamber flame tubes;

(b) throttle valve 63 designed for mechanical control of fuel supply into the engine and for stopping the engine;

(c) constant pressure valve 16 serving to maintain fuel constant pressure upstream of the main regulating pump units, so as to preserve their adjustment irrespective of any changes in the pump operating duty;

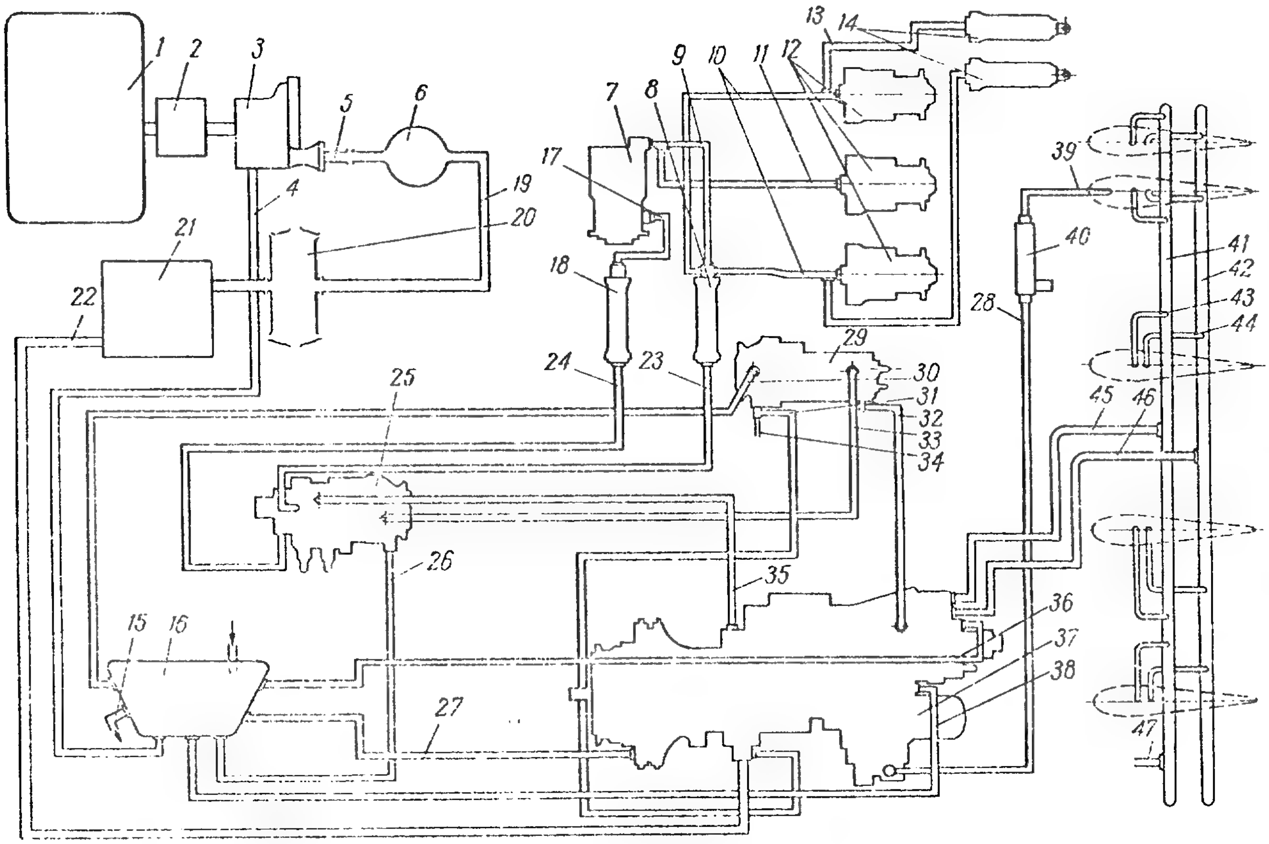
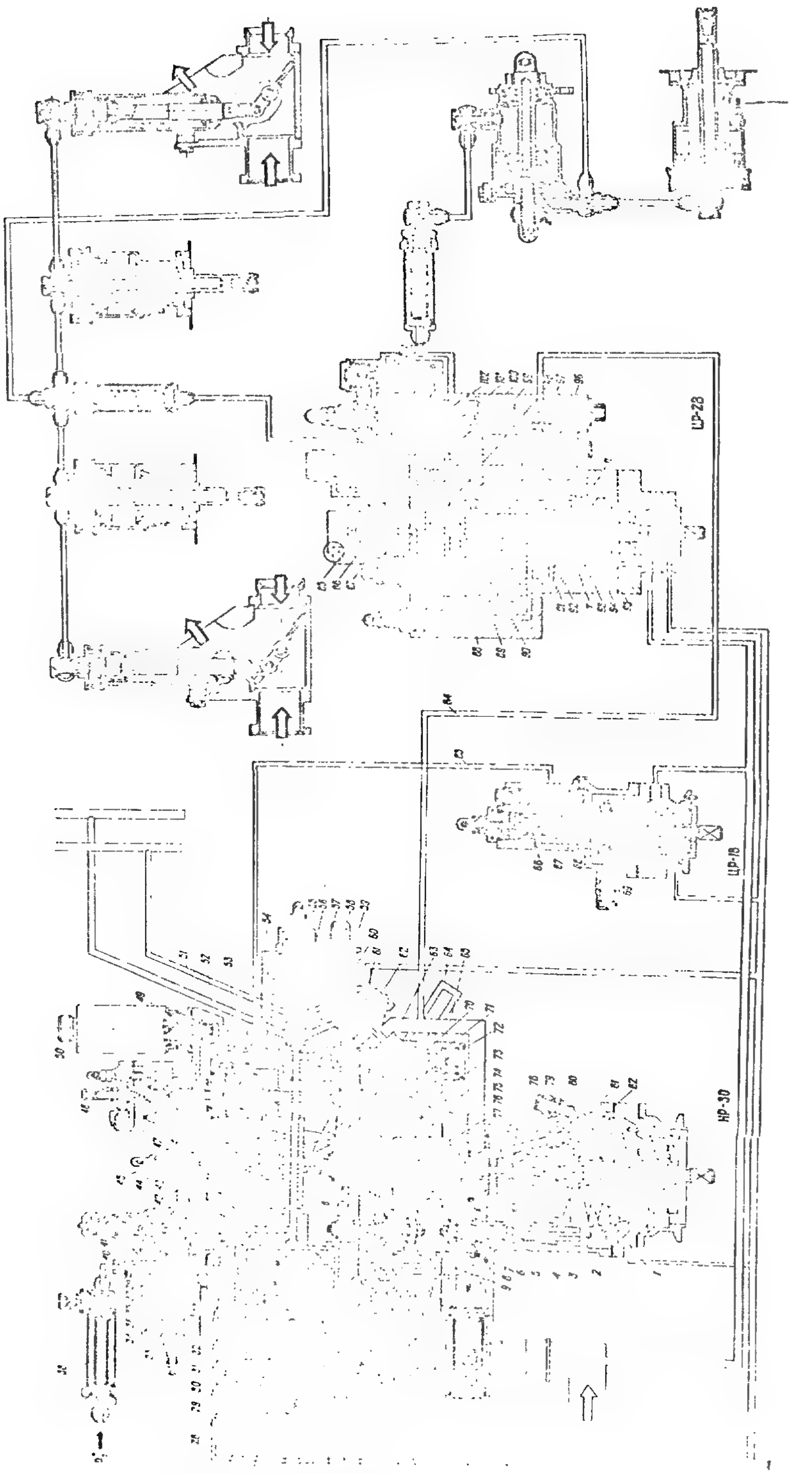


FIG. 25. ENGINE FUEL SUPPLY SYSTEM DIAGRAM

1 – fuel tank, 2 – aircraft booster pump; 3 – booster pump ЭЦН-44-ПЗТ, 4 – ЭЦН-44-ПЗТ pump shaft sealing unit drain pipeline; 5 – pipeline conveying fuel to flowmeter; 6 – flowmeter; 7 – hydraulic cylinder controlling position of inlet guide vane (IGV) assembly; 8 – fuel filter; 9 – pipeline supplying fuel to IGV control hydraulic actuator; 10 – pipeline conveying fuel to air blow-off shutter hydraulic actuator; 11 – pipeline conveying fuel to air blow-off shutter hydraulic actuator; 12 – hydraulic actuators operating air blow-off shutters aft of 4th and 5th stages of compressor high-pressure section; 13 – pipeline supplying fuel to butterfly valve hydraulic actuator; 14 – hydraulic actuators controlling air bleed butterfly valves aft of 5th and 10th stages of compressor high-pressure section, 15 – pipeline conveying fuel from drain tank to centrifugal breather drain pipe; 16 – drain tank; 17 – pipeline supplying fuel into spring chamber of IGV control hydraulic actuators, 18 – fuel filter, 19 – oil cooler fuel supply pipeline, 20 – fuel-cooled oil cooler; 21 – fuel filter, 22 – pipeline feeding fuel to fuel regulating pump HP-30; 23 – fuel filter delivery pipeline; 24 – fuel filter delivery pipeline; 25 – centrifugal speed governor HP-2B, 26 – fuel drain pipeline running from shaft sealing unit of HP-2B governor; 27 – fuel drain pipeline running from shaft sealing unit of fuel regulating pump HP-30, 28 – pipeline delivering air to automatic starting control unit; 29 – centrifugal speed governor HP-1B, 30 – fuel drain pipeline running from shaft sealing unit of speed governor HP-1B; 31 – fuel return pipeline running from speed governor HP-1B to inlet of fuel regulating pump HP-30; 32 – pipeline delivering fuel from hydraulic decelerator of fuel regulating pump HP-30 to speed governor HP-1B, 33 – fuel drain pipeline running from speed governor HP-2B to speed governor HP-1B; 34 – pipeline used for measuring fuel pressure at inlet to fuel regulating pump HP-30, 35 – pipeline delivering high-pressure fuel to speed governor HP-2B; 36 – pipeline used for draining fuel from manifolds during engine shut-down, 37 – fuel regulating pump HP-30, 38 – automatic starting control unit drain pipeline; 39 – filter air delivery pipeline; 40 – air filter provided with pressure relief valve, 41 – small-slot (primary) fuel manifold, 42 – large-slot (main) fuel manifold; 43 – burner small-slot fuel delivery pipeline; 44 – burner large-slot fuel delivery pipeline; 45 – pipeline carrying high-pressure fuel to fuel manifold; 46 – pipeline carrying high-pressure fuel to fuel manifold, 47 – pipe connection for measuring fuel pressure in small-slot manifold.



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(d) all-speed governor tachometric element 76 incorporated in the fuel regulating pump and designed to automatically maintain predetermined rpm of the compressor high-pressure rotor at speed exceeding 9700 rpm (83%);

(e) hydraulic decelerator 53 serving for smooth (at a predetermined rate) readjustment of the spring of the speed governor slide valve, when the throttle valve is abruptly shifted, which ensures a gradual change in the engine speed;

(f) fuel pressure rise limiter 26 (upstream of the fuel burners) designed for smooth increase of fuel pressure somewhat ahead of the predetermined time, necessary for normal acceleration of the engine from the idle rating to maximum take-off rating;

(g) flow divider 56 serving for distributing fuel between the fuel burner passages depending on the pressure of fuel upstream of the divider;

(h) automatic starting fuel control unit with altitude compensator 41 designed for ensuring normal starting of the engine on the ground and in the air within an optimum time period, involving no temperature surge aft of the turbine;

(j) differential valve 18 serving for maintenance of constant pressure drop across the pump throttle valve at the ratings below the beginning of the automatic operation speed, which ensures constant fuel supply with the throttle valve stationary and constant speed of the compressor high-pressure rotor, if the flight conditions do not change;

(i) drip valve 59 used for draining fuel from the fuel manifolds into the drain tank, when the engine is being stopped;

(k) overtemperature limiter 42 through 50 (unit OT) is actually an overtemperature limiter actuating unit incorporated in exhaust overtemperature control system ПТ-35.

When a signal is sensed by the overtemperature limiter actuating unit from overtemperature amplifier УРТ-19А-2Т, the former increases the amount of fuel returned from the hydraulic decelerator piston chamber. As a result, the compressor high-pressure rotor speed reduces with a resultant reduction in the gas temperature aft of the turbine;

(l) slide valve 47 restricting the overtemperature limiter actuating speed, as 100 per cent pulse ratio signal is obtained from overtemperature amplifier УРТ-19А-2Т.

Centrifugal speed governor ЦР-2В comprises a speed transmitter employing a tachometric element. The unit serves for automatic change-over of the position of the hydraulic actuators and the microswitch, depending on the speed of the compressor high-pressure rotor. The ЦР-2В unit ensures:

(a) the operation of the hydraulic actuator controlling the air blow-off shutters aft of the 4th and 5th stages of the compressor high-pressure section, the IGV hydraulic actuator, and butterfly valves in the air bleed system of the hydraulic actuators controlling the position of the air supplying hot air to the compressor first spool IGVs and air intake from the tenth or fifth stage of the compressor high-pressure section. The above listed actuators are synchronously controlled by the same signal sent from the ЦР-2В centrifugal governor;

(b) disengagement of starter-generators СТГ-12ТВМО in the process of starting and engagement of the ice warning system.

The ЦР-1В unit is essentially a centrifugal speed governor designed for limiting maximum speed of the compressor low-pressure rotor.

The purpose of the ПРТ-35 overtemperature control system is to protect the engine from excessive temperature aft of the turbine at the engine maximum take-off rating.

The overtemperature control system comprises 12 twin thermocouples T-99-1 (hot junctions of alloys НК and СА), overtemperature amplifier УРТ-19А-2Т, and overtemperature limiter (unit ОТ) incorporated in fuel regulating pump НР-30 (Fig.26).

The overtemperature amplifier is designed to convert the voltage difference signals received from the presetter and thermocouple unit into rectangular-shaped D.C. voltage pulses.

With an increase in discrepancy of the actual and preset exhaust gas temperatures, the duration of the signal sensed by proportional solenoid 50 of the overtemperature limiter as related to the total cycle period increases linearly from zero to 100 per cent.

Proportional solenoid 50 transforms the rectangular-shaped voltage pulses received from amplifier УРТ-19А-2Т into translational motion of valve 49 which closes or opens the hole for additionally draining fuel from cavity "б" of the overtemperature limiter, thereby varying the pressure value in the cavity. The pressure change in cavity "б" brings about a change in the position of slide valve 42, which increases or decreases the amount of fuel additionally drained from the hydraulic decelerator piston chamber of fuel regulating pump НР-30.

With an increase in the turbine outlet actual gas temperature relative to the preset value, the УРТ-19А-2Т amplifier increases the pulse duration ratio, slide valve 42 increases the amount of fuel drained from the hydraulic decelerator piston chamber, which brings about readjustment of the speed governor of the fuel regulating pump to a lower speed of the compressor high-pressure rotor, hence to the reduction in the exhaust gas temperature to the preset value. If, however, the pulse duration ratio amounts to 100%, the compressor high-pressure speed may not reduce below 10,500 ± 75 rpm (89.5 - 90.5%), since a special slide valve will close the fuel drain line from the hydraulic decelerator piston chamber, thereby limiting the speed reduction degree ensured by the ПРТ-35 overtemperature control system.

When the exhaust gas temperature aft of the turbine is equal to the preset temperature limit, the УРТ-19А-2Т amplifier sends rectangular-shaped voltage pulses with 50 per cent duration ratio to proportional solenoid 50.

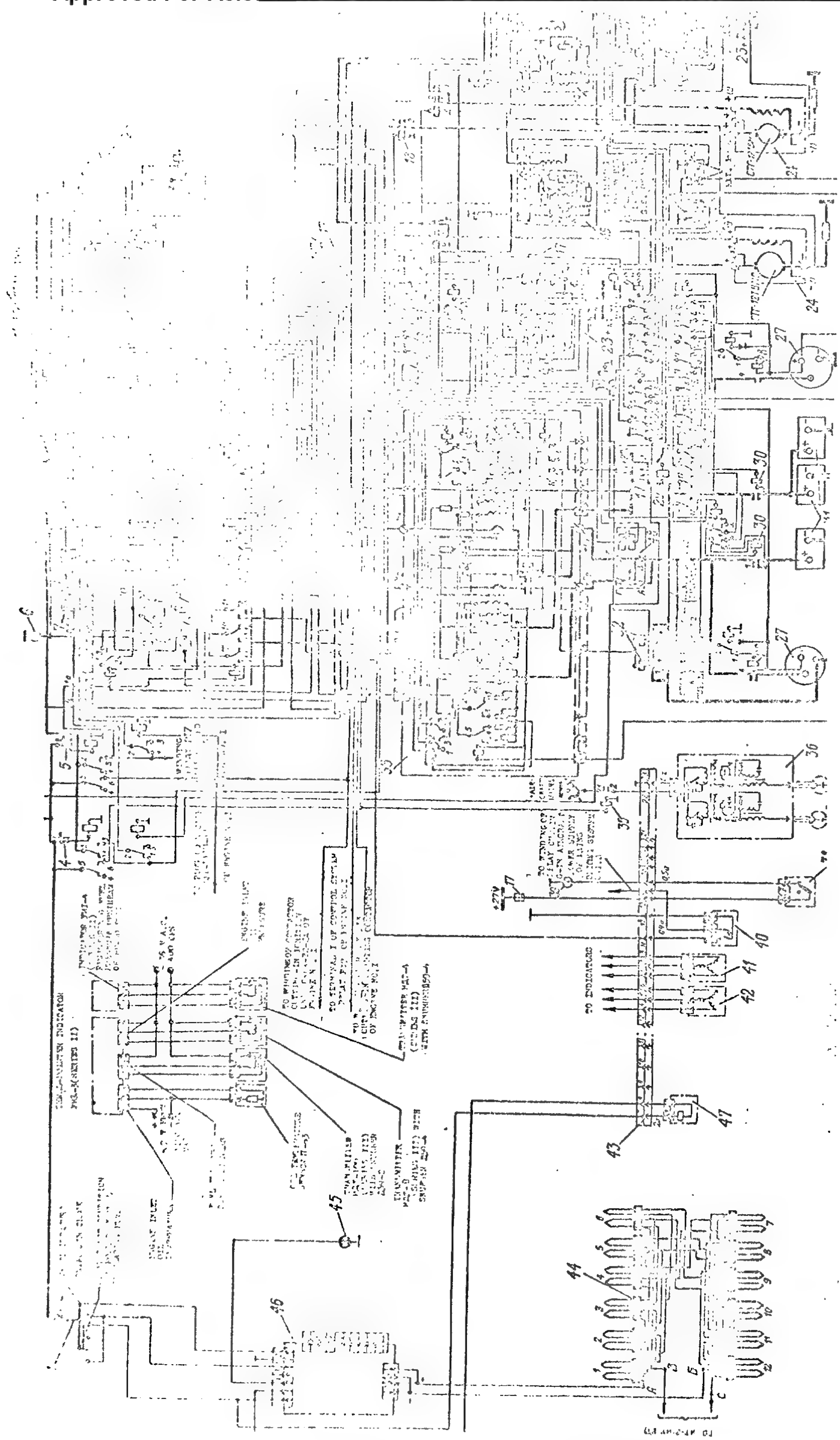
The overtemperature controller is adjusted to a temperature exceeding by 15°C the turbine outlet gas temperature at the engine maximum take-off rating under the ambient air temperature +15°C with no air bled for the aircraft needs.

To check the operation of the overtemperature control system, provision is made of a tumbler labeled ПРТ TEST (КОНТРОЛЬ ПРТ); when the tumbler is switched on, the ПРТ-35 overtemperature control system will limit the turbine outlet gas temperature to a value by 110°±10°C less than the maximum temperature limit (the presetter adjustment value).

9. STARTING SYSTEM

A. Voltage Supply and Starting System СПЗ-30 (Fig.27)

The СПЗ-30 voltage supply and starting system is designed for automatic successive starting of two engines Д-30 on the aircraft from starter-generators fed according to 24 x 48 V scheme, as well as for feeding voltage into the aircraft mains.



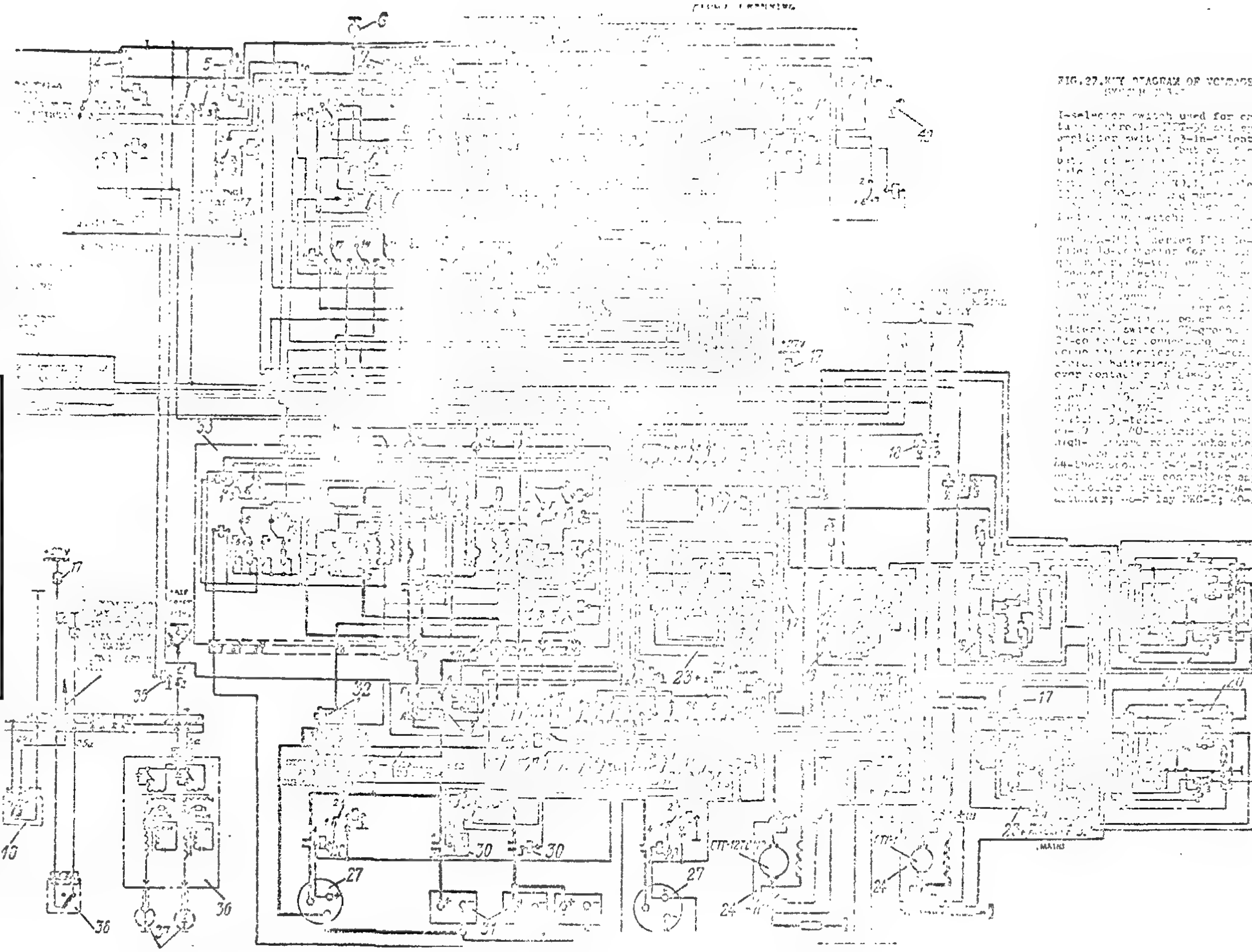


FIG. 27. KEY DIAGRAM OF VOLTAGE SUPPLY AND STARTING [illegible]

1–selector switch used for checking operation of overtempera- [illegible] amplifier switch; 3–in-flight start system circuit breaker; [illegible] in-flight start [illegible] operation tel. [illegible] automatic starting con- [illegible] button; [illegible] switch; [illegible] lamp indicating malfunctioning [illegible] electric motor; 17–safety fuse; 18–contactor for [illegible] power supply to starter – [illegible] (same as 11); 20–circuit [illegible] against overvoltage; 21–genera- [illegible] reverse current cut-out [illegible] current cut- [illegible] starters CCT – [illegible] storage battery switch; [illegible] supply source receptacle; [illegible] 29–lumbar [illegible] of aircraft storage batteries; [illegible] batteries [illegible] 32–change- over contact [illegible] circuit bre- aker [illegible] ignition unit [illegible] position limit switch; [illegible] lamp indicating that [illegible] are in positi- on [illegible] speed governor [illegible] high- [illegible] generator; 42–pressure low- [illegible] plug connector; 44–[illegible] lamp indicating failure of [illegible] controller amplifier; 46 – overtemperature controller [illegible] 47–overtemperature controller actuator; [illegible] relay [illegible] 49–limit switch of closed doors.

[redacted]

The voltage supply and starting system includes the following main units: two starter-generators, capacitance-type ignition system, fuel control unit, automatic starting and voltage supply control system. Each of the engines is started with the aid of two starter-generators СТГ-12ТМО which operate as starters during the procedure. At the end of the starting cycle, when the engine runs independently, the starter-generator is switched over to generator duty.

When operating as starters, the СТГ-12ТМО starter-generators are supplied from two storage batteries 12САМ-55 arranged in the aircraft, or from a ground power source whose voltage may be switched over from 24 to 48 V, or from two starter-generators (of the engine already running) at a speed of not less than 7200 rpm in conjunction with the on-board storage batteries.

Purpose and Units of Voltage Supply and Starting System

The voltage supply and starting system comprises the following units and accessories: starting control unit АПД-19БД (series II), starter-generators СТГ-12ТМО, starter-generator control panel ПСГ-2А (series II), ignition unit СКНА-22-2А with ignition plugs СП-06ВП, electro-hydraulic switch incorporated in centrifugal governor ЦР-2В and serving for disengagement of the starter-generators, on-board storage batteries 12САМ-55, reverse current cut-out relays ДМР-400Т (series II), voltage regulators РН-180 (series II), switching and protecting equipment in accordance with the system key diagram (Fig.27).

Automatic starting control unit АПД-19БД (series II) and the electro-hydraulic switch of centrifugal governor ЦР-2В serve as control units. The rest of the units are intended for the respective actuating purposes.

1. Automatic starting control unit АПД-19БД (series II) is designed for controlling the starter-generators according to a special time program during starting the engine and for switching them over to the generator duty. It is used also for switching on and off the engine ignition system.

2. The ЦР-2В centrifugal governor electro-hydraulic switch is designed for deenergizing the starting system as soon as the compressor high-pressure rotor gains a speed of 4500 ± 200 rpm.

3. Starter-generator control panel ПСГ-2А (series II) serves for following up the control signals generated by automatic starting control unit АПД-19БД (series II) for switching on and controlling the starter-generators. The unit also maintains the starter-generator capacity constant in the process of starting.

4. Starter-generator СТГ-12ТМО is designed for starting the engine when operating as a starter, and for feeding voltage into the aircraft mains, when operating at the generator duty.

5. Ignition unit СКНА-22-2А together with two semi-conductor ignition plugs СП-06ВП are used for igniting fuel-air mixture in the combustion chamber flame tubes during starting the engine on the ground and in flight.

6. The purpose of storage battery 12САМ-55 is to feed the aircraft mains with direct current. Each storage battery consists of two series half-battery sets with a rated voltage of 12 V each.

7. Reverse current cut-out relay ДМР-400Т (series II) is designed for automatic switching on the starter-generator to the aircraft mains in case the starter-generator operates in the generator duty and its output voltage exceeds the voltage in the

[redacted]

aircraft mains, as well as for switching off the generator from the aircraft mains, when its voltage is less than that in the aircraft mains.

8. Voltage regulator PH-180 (series II) is designed for keeping the starter-generator voltage within certain predetermined limits during its operation at the generator duty.

As the same time the voltage regulator ensures proper distribution of load between two starter-generators operating in parallel.

9. Circuit breaker АЗП-8М (series IV) is intended to protect the D.C. aircraft mains from overvoltage that may take place after failure of the voltage regulator or disconnection of any of the starter-generators operating in parallel.

10. Relay PPC-1 is used in the system for interlocking starting of engine Д-30 (rendering it impossible), when the starting is conducted according to the СПЗ-30 system with the aid of only one starter-generator.

Starting System Operation

The engine starting process on the ground, when powered from two storage batteries 12САМ-55 installed in the aircraft, occurs in three stages:

The 1st stage - two starter-generators spin the compressor high-pressure rotor and the associated rotor of the first turbine to an rpm value, at which the high-pressure rotor draws in substantial amount of air and builds up a pressure sufficient for steady combustion of fuel. Fuel is ignited by ignition plugs СП-06ВП in the engine combustion chamber at the compressor high-pressure rotor speed amounting to 1000 or 2000 rpm.

The 2nd stage - the compressor high-pressure rotor is still spinned by the starter-generators under assistance of the first turbine. To attain faster acceleration of the engine, the power sources are switched over from 24 V to 48 V as 10 or 11 sec elapse from the beginning of the starting procedure.

The 3rd stage - the compressor rotors are spinned to idle rpm value by the turbine, the starter-generators being cut out of the operation.

The ignition system is cut in simultaneously with the starter-generators and functions within 45 sec. Then the starter-generators are switched over to the generator duty. Automatic starting control unit АПД-19ВД (series II) is set at its initial state.

In the event the high-pressure rotor gains a speed of 4500 ± 200 rpm before 45 - 60 sec elapse, the starter-generators are switched over to the generator duty by the electro-hydraulic switch incorporated in centrifugal governor ЦР-2В. Should the compressor high-pressure rotor reach a speed of 4700 rpm ahead of the specified time and the electro-hydraulic switch fail to operate, the starter-generators must be switches off manually by depressing the ABORT (ПРЕКРАЩЕНИЕ ЗАПУСКА) button, to prevent the starter-generators from failure.

The engine starting on the ground from an external power source yielding 24x48 V current is carried out in the same sequence, with the power supply source switch selected to the GROUND POWER SUPPLY SOURCE position (АЭРОДРОМНЫЕ ИСТОЧНИКИ).

[redacted]

Engine False Start

The engine false start is carried out with the aim of priming the engine hydraulic systems and checking them for tightness. To perform a false start, it is imperative to disconnect the engine ignition system from the aircraft mains, having switched off the ignition unit circuit breaker, set all the switches in positions corresponding to the engine ground starting, then press and release the ground start button.

The starting system units are switched on and off and the starting system functions in the same way as during the above described automatic starting of the engine on the ground. However, fuel-air mixture is not ignited in the engine combustion chamber, because the ignition system is cut off in this case. The starting system is disengaged according to the respective time schedule.

Engine BLOW-OUT

Prior to starting the engine it is desirable to motor it over. The function selector must be set in the BLOW OUT (ХОЛОДНАЯ ПРОКРУТКА) position. The starting system units are switched on and off and the starting system functions in the same way as during automatic starting of the engine on the ground, exclusive of the fact that the ignition system remains cut off and the starting system units are fed with 24 V current throughout the procedure, which lasts 34 ± 2 seconds.

Engine Starting in Flight

The engine may be started in flight at an altitude of up to 9000 m. To start the engine in flight, proceed as follows: set switch GROUND-AIR (ЗЕМЛЯ-ВОЗДУХ) in the AIR (ВОЗДУХ) position, select the function switch to position STARTING, then press the IN-FLIGHT START button. As a result, the engine ignition system sets functioning for 45 ± 2 sec. The IN-FLIGHT START operating cycle of automatic starting control unit АПД-19БМ (series II) lasts for 48 sec.

To ensure reliable starting of the engine in flight, provision is made in the electric starting system for manual starting in addition to the above described automatic starting in flight. Manual starting is accomplished with the aid of the IN-FLIGHT START button, which should be kept depressed until fuel starts burning in the engine but for not more than 60 sec.

Discontinuing Starting Procedure

The engine electric system provides for discontinuation of any starting cycle.

To discontinue engine starting it will suffice to depress and release the starting abortion button. As a result, the timer incorporated in automatic starting control unit АПД-19БМ (series II) is switched over for a rapid accomplishment of its operating cycle (within 3 sec), and all the engine starting units are switched off.

After the starting abortion button is depressed, the same events take place in the operation of the electric starting system as in the case of automatic discontinuation of the engine starting by the electro-hydraulic switch of centrifugal governor ЦР-23 which controls the starting process with regard to engine speed.

[redacted]

To prevent overspeeding of the starter-generators operating in the starter duty in the event of damage to the safety coupling (limiting the torque value transmitted from the drive), provision is made for relay PKC-1 connected in the power supply circuit of the starter-generators. An indicating light is also provided in the system to warn on malfunctioning of the starter-generators operating in the starter duty.

Upon completion of the GROUND ENGINE STARTING cycle (ЗАПУСК ДВИГАТЕЛЯ НА ЗЕМЛЕ) the starter-generators are switched over to the generator duty to supply D.C. into the aircraft mains and boost-charge the aircraft storage batteries.

B. Starter-Generator CTГ-12ТМО (Fig.28)

The starter-generator is a D.C., shunt-wound, six-pole, heat-resistant machine cooled with ram air.

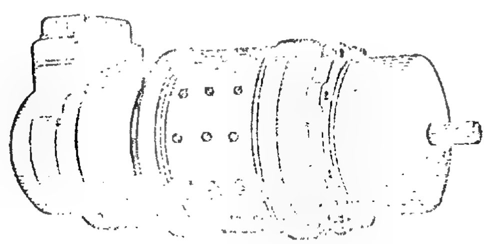


FIG. 28. STARTER-GENERATOR CTГ-12ТМО

The overrunning clutch and the reduction gear arranged in the drive end allow the starter-generator (when operating as a starter) to run at a gear ratio between the rotor and the reduction gear output shaft amounting to $i = 3.167$, which aids in the output torque value. After the engine has been started, the starter-generator changes over to the generator duty, the gear ratio in this case being equal to $i = 1$.

Main Rated Technical Data

Generator Duty

1.	Voltage, V	28.5
2.	Output current, A	400
3.	Output (at 30 V), W	12,000
4.	Speed variation range, rpm	4200 - 9000
5.	Operating duty	continuous

Starter Duty

1.	Supply voltage, V	30
2.	Torque, kgm	12
3.	Output shaft speed, rpm	750 ± 10%
4.	Current consumed (average total), A	470, max.
5.	Operating duty	intermittent: 50 sec running

periods at 3 min intervals. After 5 above cycles complete cooling is required

In the course of the service run when used in conjunction with the СПЗ-30 starting system, the starter-generator may be operated under the following conditions:

1. Output shaft load .... engine rotor
2. Supply voltage, V .... 60, max
3. Mean square current, A .... 510, max.
4. Output shaft speed at disengagement instant, rpm .... 3500, max.
5. Operating duty .... intermittent, in accordance with operation of СПЗ-30 system
6. Service life:
   starter duty .... 1200 engagements within 1000 engine operating hours
   generator duty .... 1000 hours

It is allowed to load the starter-generator under ground conditions with 200 A for 20 minutes without cooling air supply at the armature speed not less than 3700 rpm.

7. Weight, kg .... 37, max.

The starter-generator is designed for normal operation under the following conditions:

(a) altitude relative to the sea level, m .... 12,000 max.
(b) ambient air temperature range, °C .... (-60) - (+90)
(c) ambient air relative humidity at a temperature of +20 ± 5°C, per cent .... 98, max.
(d) impact overload within a frequency range of from 40 to 100 cps .... 4 g, max.

The starter-generator is a semi-closed machine having inlet and outlet ports for cooling air. Installed at the drive end of the starter-generator is a centrifugal fan which cools down the machine on the ground for 20 min with no cooling air supply.

C. Ignition System Units
(Fig.29)

To ignite fuel-air mixture in the engine combustion chamber flame tubes, use is made of low-voltage, capacitor-type ignition system comprising ignition unit СКНА-22-2А, two surface discharge semi-conducting ignition plugs СП-06ВП supplied as a set complete with contact devices КУ-30Б and elbows УЗ-90-184ЕТ.

The ignition unit is installed in the upper part of the by-pass duct entry housing, and the ignition plugs are mounted in combustion chamber flame tubes Nos 2 and 11.

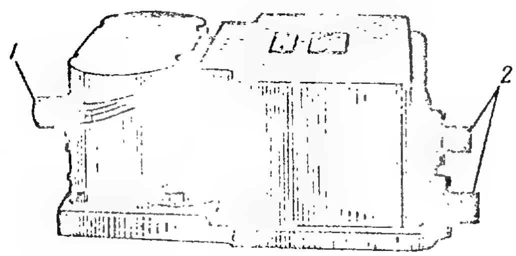


FIG. 29. IGNITION UNIT СКНА-22-2А
1 – power supply plug connector; 2 – unions for connection of high-voltage ignition plug cables.

Operation of the ignition unit is based on the discharge of the reservoir capacitor. When voltage across the capacitor plates is built up to a value, equal to the puncture voltage of discharger P-22, the capacitor discharges, as a result of which a surface creeping discharge is formed between the ignition plug electrodes, which occurs at a rate of 6 to 31 discharges per second at a supply voltage of 27 ± 1 V fed to the plug connector of the ignition unit. To ensure serviceability of the ignition system and increase puncture voltage across the ignition plugs, and activator is connected into the circuit.

The activator is actually an oscillatory circuit in which high-frequency electric oscillations are excited at the beginning of the discharge, as a result of which high voltage is produced in the secondary winding of the activator transformer, which is sufficient for jumping the ignition plug gap, separated by a semi-conductor layer.

Ignition plug СП-06ПЗ (Fig.30) is an integral unit with ceramic insulation. The spark gap of the plug is formed by the ceramic insulator surface between the central and side electrodes covered with a semi-conductor material. For protection of the ignition plug against overheating, its body is fitted with a cooling shroud having radial holes for supply of cooling air from the combustion chamber diffuser to the working end of the ignition plug.

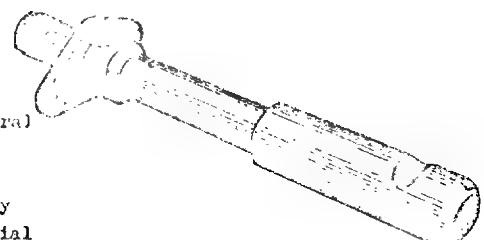


FIG. 30. IGNITION PLUG СП-06ПЗ

10. ELECTRIC EQUIPMENT AND MEASURING INSTRUMENTS

(a) Turbine Outlet Gas Overtemperature Controller

Turbine outlet gas overtemperature control system ПРТ-35 is designed for limiting the turbine outlet gas temperature when the engine is running at the maximum rating.

The overtemperature control system comprises the following units:

1. Temperature transmitter – a set of 12 twin thermocouples T-99-1 (Fig.34)
2. Amplifier УРТ-19А-2Т (Fig.31).
3. Actuating unit – fuel regulating pump НР-30 (Fig.26).
4. Connecting wire harness (see Fig.35).

Overtemperature amplifier УРТ-19А-2Т is installed in the aircraft, the remaining components of the ПРТ-35 system are mounted on the engine.

The preset temperature limit may vary within a range of from 570 to 670°C.

The D.C. amplifier load is essentially an electromagnet incorporated in fuel regulating pump HP-30. When energized, the electromagnet readjusts the fuel regulating pump for lower output. As a result, less fuel is supplied to the fuel burners, which brings about a reduction in the turbine outlet gas temperature.

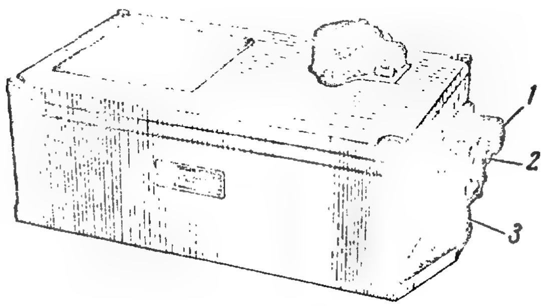


FIG. 31. AMPLIFIER УРТ-19А-2Т
1 – plug connector for jointing thermocouples; 2 – plug connector for coupling test system; 3 – power supply plug connector.

With an increase in the turbine outlet gas temperature, the electromagnet will remain energized for a longer period of time. In case of overtemperature the electromagnet of fuel regulating pump HP-30 will be energized continuously, until the temperature drops to the preset value.

In case of a sharp increase in the turbine outlet gas temperature, when the fully energized electromagnet of fuel regulating pump HP-30 fails to reduce it, as, for instance, during engine surging or failure of the electromagnet to get deenergized for a long period of time, the fuel regulating pump will send a failure signal (FS). At the same time, the pump protection system operates, disengaging the electromagnet of the fuel regulating pump from the temperature control channel.

To improve the operation of the УРТ-19А-2Т amplifier under conditions of varying supply voltage, the system is provided with an electronic voltage stabilizer.

The system is furnished also with a special device for eliminating the effect of contact instability (alternating taking up and breaking of the contact) in the thermocouple circuit on the operation of the overtemperature control system.

When the turbine outlet gas temperature is lower than the preset temperature limit, or in case of failure of the thermocouples, the overtemperature controller is not engaged in the operation of the engine fuel control system.

(b) Engine Casing Vibration Measuring Equipment ИВ-200Е (Fig.32)

The ИВ-200Е vibration measuring equipment is intended for checking engine vibrations in service, while in use on the aircraft.

Vibration stresses in the engine structure are determined by the vibration overload measured with the aid of equipment ИВ-200Е.

The ИВ-200Е equipment serves two engines and comprises one two-channel electronic unit 2, two vibration pick-ups 3 and two indicators 1.

The operating principle of the vibration measuring equipment is based on transformation of a pick-up signal with the aid of an electronic unit into a rectified signal which cuts in the warning system as soon as the vibration speed limit is attained. The actual value of vibration speed is measured by means of an indicator.

Each channel of the apparatus is connected with one vibration pick-up МВ-25Б-В, intended to convert the rate of steady linear vibrations in the vertical plane into electric voltage.

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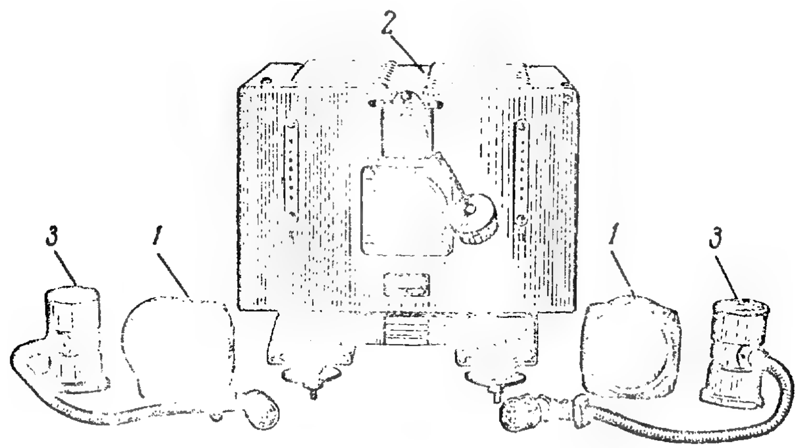

FIG. 32. ENGINE CASING VIBRATION MEASURING EQUIPMENT ИВ-200Е:
1 – indicator; 2 – two-channel electronic unit; 3 – vibration pick-ups.

The indicating warning light comes on as soon as the actual vibration speed amounts to the preset critical value.

To check the vibration equipment for serviceability, it is necessary to energize the equipment and press the TEST button. At that moment, the pointer of the indicator should show within 60 - 100 mm/sec. The indicator measures actual vibration speed, its scale being graduated in mm/sec from 0 to 100 with a graduation value of 5 mm/sec.

The two-channel electronic unit comprises two amplifier channels (with a pass band of from 50 to 200 cps) and a common power supply unit, which are constructed and assembled as separate units.

The face panel of the electronic unit carries a plug connector common for both channels. Apart from the amplifier input and output wires, the plug connector receives the power supply cables running from the aircraft mains. Arranged on the face panel is also a TEST plug connector intended for connection of special control unit УПИВ-200.

The vibration pick-up is installed in the area to be checked for vibration on a special bracket provided on the engine.

The electronic unit is mounted in a convenient location in the aircraft fuselage. The indicator is necessarily installed in the vertical position.

(c) IGV Position Signalling System
(Fig.33)

The signalling system indicating the position of the IGVs of the compressor high-pressure section comprises microswitch A-812K, an indicating light, and connecting wires. The microswitch is designed to close and open the power supply circuit of the indicating light. The microswitch is mounted complete with the IGV position indicator on the flange located on the shell of the combustion chamber forward casing.

[redacted]

The signalling system indicating the position of the compressor high-pressure section IGVs functions as follows: as the compressor high-pressure rotor gains a speed of n_2 = 1500 ± 200 rpm in the process of engine starting, the pointer of the IGV actuating device moves off micro-switch rod 3. The microswitch operates, closing the indicating light circuit, and the light comes on, indicating that the compressor high-pressure section IGVs are set at an angle of − 10 deg.

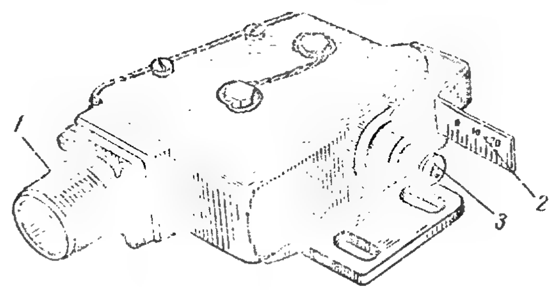

FIG. 33. MICROSWITCH PROVIDED WITH SCALE AND BRACKET
1 – plug connector; 2 – scale, 3 – microswitch rod.

With the compressor high-pressure rotor speed amounting to $n_2 = 9400^{+125}_{-175}$ rpm, the pointer of the IGV actuating device depresses microswitch rod 3. The microswitch operates and the indicating light goes out, showing that the IGVs are set at the zero angle.

As the compressor high-pressure rotor slows down to n_2 = 9100 ± 100 rpm, the indicating light comes on again to show that the IGVs are turned to − 10 deg. With further reduction of the speed (below 1500 ± 200 rpm) the indicating light goes out again showing that the compressor high-pressure section IGVs are shifted to the zero angle position.

(d) Measuring Instruments

For checking engine operation, the following measuring devices are provided:

1. Compressor high-pressure rotor tachometer generator ДТЭ-5Т. The tachometer generator is mounted on the upper drive gear box.

2. Compressor low-pressure rotor tachometer generator ДТЭ-5Т. The tachometer generator is installed on the right-hand drive gear box. The ИТЭ-2Т tachometer indicators of both compressor sections are installed in the aircraft crew cabin.

3. Transmitter П-63 for measuring oil temperature at the engine inlet. The transmitter is mounted on the lower drive gear box.

4. Transmitters: ИДТ-8 (series III) for measuring oil pressure at the engine inlet; ИДТ-100 (series III) for measuring fuel pressure in the primary manifold; ИДТ-4 (series III) for measuring fuel pressure at the inlet to the fuel regulating pump.

Transmitters ИДТ-4 (series III) and ИДТ-8 (series III) are used in service with snubbers Д59-4; the ИДТ-100 (series III) transmitter is used with snubber Д59-2. Transmitters П-63, ИДТ-8 (series III) and ИДТ-100 (series III) are incorporated in the electric motor indicator set ЭМИ-3РТИ. Transmitter ИДТ-4 (series III) is a component unit of fuel pressure gauge ЭМИ-4Т (series III). Transmitters ИДТ-4 (series III), ИДТ-8 (series III) and ИДТ-100 (series III) are installed on the measuring instrument panel located on the combustion chamber forward casing.

5. Exhaust gas thermometer. The exhaust gas temperature is measured by means of twin thermocouples Т-99-1 (Fig.34) and high-accuracy meter ИТ-2Т. Installed on the

engine are twelve thermocouples T-99-1 with hot junctions of HK-CA alloys, which serve as temperature sensors.

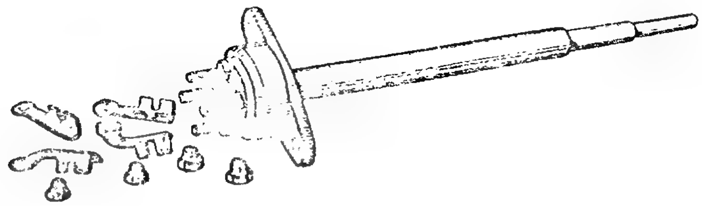

FIG. 34. THERMOCOUPLE T-99-1

Thermocouples T-99-1 are equally spaced in the engine main duct. Half of the twin thermocouples are connected to overtemperature controller amplifier УРТ-I9T-2T, the rest of the thermocouples are connected to turbine outlet gas temperature meter ИТ-2Т. Gas temperature meter ИТ-2Т and amplifier УРТ-I9A-2T are installed in the aircraft. The thermocouples for the УРТ-I9A-2T amplifier and the ИТ-2Т meter are connected in the following similar way: the respective thermocouples are connected into four series groups of three thermocouples each connected in parallel. The thermocouples are interconnected in groups by means of copper non-shielded wire 0.75 mm^2 in cross-section.

The connecting wires are laid out in a special manifold with the aim of shielding and ease of installation. Appropriate unions are provided in the manifold to lead the wires out and to connect them to the thermocouples with the use of lugs soldered to the wire ends.

From the manifold the shielded wires are laid out through the load-carrying strut of the second turbine rear support to the connecting block, located on the combustion chamber rear casing.

The circuits from the block to amplifier УРТ-19A-2T and meter ИТ-2Т are made of shielded wires.

When the engine is running, the thermocouple hot junctions are blown with exhaust gases, due to which an electromotive force is generated in the thermocouples as a function of the turbine outlet gas temperature.

11. FIRE-FIGHTING SYSTEM
(Fig.36)

The engine fire-fighting system is comprised of fire alarm system 2С7К and a fire-extinguishing system.

(a) Fire Alarm System

The engine fire alarm system is designed for making a light (or sound) signal in case of fire occurring in the engine internal and external protected areas as well as for effecting the automatic control of the fire-fighting system.

The fire alarm system consisting of four fire detectors and one actuating unit is designed for both engines installed in the aircraft. Each engine is equipped with two fire detectors ДП-11 accommodated in the cavity between the shaft tube and the combustion chamber inner casing.

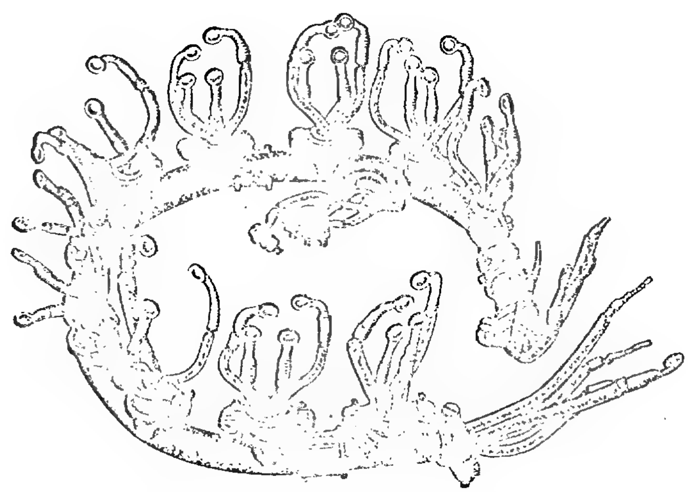

FIG. 35. THERMOCOUPLE CONNECTING WIRE HARNESS

The purpose of fire detectors ДПИ-11 is to send signal to the actuating unit in case of fire in the engine internal cavities under protection. The minimum limit temperature at which a signal is sent by the fire detectors is 550+150°C.

The fire detector operating principle is based on the thermoelectric effect. The sensing element of each fire detector is comprised of a set of thermocouples made of alloys HX and CK and connected in series.

(b) Fire-Extinguishing System

The fire-extinguishing system consists of bottle 1 filled with fire extinguishant freon 114B-2 (the weight of the extinguishing agent in the bottle is 2.725 kg), pipeline 9 delivering fire extinguishant into the cavity between the shaft tube and the combustion chamber inner casing, pipeline 12 for delivery of fire extinguishant into the shaft tube, diaphragm 8 installed in the tee-piece to which pipeline 3 is attached for feeding the engine fire-extinguishing system with extinguishant from the aircraft fire-fighting system.

The fire-extinguishing system operates as follows: when the engine internal cavity under protection (that located between the shaft tube and the combustion chamber inner casing) is set on fire, the 2CTA fire alarm system energizes the fire warning indicating light and the fire-extinguishing system. As a result, fire extinguishant Freon 114B-2 under pressure makes its way under pressure along pipeline 3, damages diaphragm 8 and is conveyed inside the engine via pipelines 9 and 12.

In addition to the above described internal fire-extinguishing system, the engine is provided with an external fire-extinguishing system (see Fig.36).

12. ENGINE EXTERNAL FITTINGS

The engine external fittings include external pipelines and hoses of the fuel supply system, the lubricating oil system, the deicing system, the air system, the breathing and fire-fighting systems, as well as the conduits and sheaths of the engine electrical system.

The identifying colours of the system pipelines are tabulated below:

System	Fuel supply	Lubricating oil	Deicing, air and breathing	Fire-fighting	Electrical
Colour	yellow	brown	black	red	silvery

The delivery pipelines of the lubricating oil system are made of 10-mm dia. piping, the oil scavenging pipelines are fabricated of piping 18 and 20 mm in diameter.

The arrangement diagram of the external pipelines on the engine is given in Fig.37.

13. ENGINE ATTACHMENT ON AIRCRAFT
(Fig.38)

Engine attachment on the aircraft is accomplished with the aid of eight brackets supplied with the engine. Seven brackets 2 are arranged symmetrically on hanger housing 1 between the forward casing and the diffuser of the combustion chamber in

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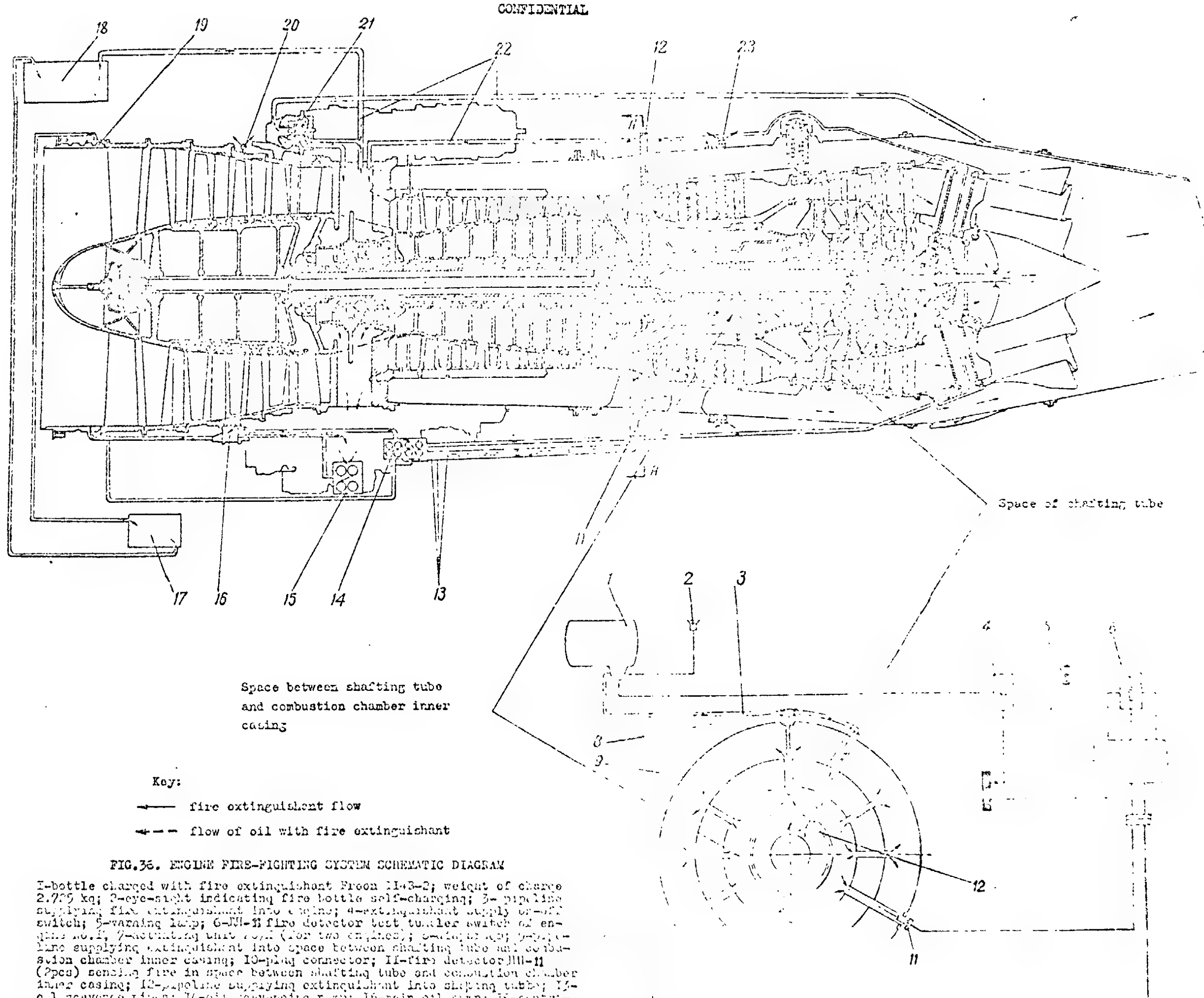

FIG.36. ENGINE FIRE-FIGHTING SYSTEM SCHEMATIC DIAGRAM

I-bottle charged with fire extinguishant Freon 114B-2; weight of charge 2.7?? kg; 2-eye-sight indicating fire bottle self-charging; 3- pipeline supplying fire extinguishant into engine; 4-extinguishant supply on-off switch; 5-warning lamp; 6-ДМ-11 fire detector test tumbler switch of engine No.1; 7-actuating unit [illegible] (for two engines); 8-[illegible]; 9-pipeline supplying extinguishant into space between shafting tube and combustion chamber inner casing; 10-plug connector; 11-fire detector ДМ-11 (2pcs) sensing fire in space between shafting tube and combustion chamber inner casing; 12-pipeline supplying extinguishant into shafting tube; 13-oil scavenge pipes; 14-oil scavenging pump; 15-main oil pump; 16-centrifugal deaerator; 17-cooler; 18-oil tank; 19-adapter for cooling oil; 20-front spray ring; 21-centrifugal breather; 22-breathing pipes; 23-rear spray ring.

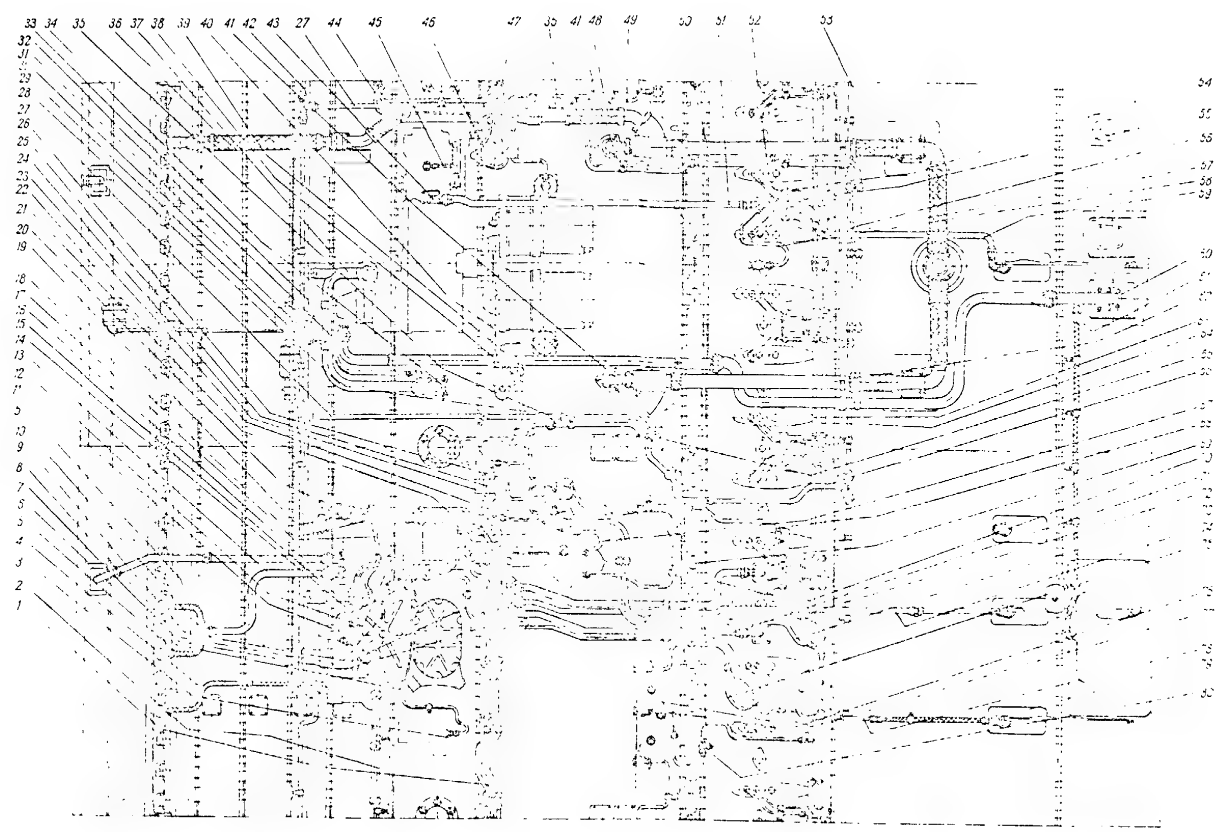

FIG. 37. ARRANGEMENT DIAGRAM OF ENGINE EXTERNAL FITTINGS AND PIPELINES

1 – pipeline draining fuel from centrifugal governor [illegible]; 2 – drain tank fuel outlet pipeline; 3 – pipeline draining fuel from centrifugal governor [illegible]; 4 – hose supplying oil to front bearing of compressor l.p. rotor; 5 – hose for scavenging oil from front bearing of compressor l.p. section rotor; 6 – [illegible] hydraulic pump drain pipeline; 7 – pipeline supplying oil to bearings of compressor and turbine [illegible]; 8 – [illegible] drain tank compressed air supply line; 9 – HP-30 fuel regulating pump drain pipeline; 10 – tee-piece for scavenging oil from front bearing of compressor low-pressure section; 11 – [illegible] pump drain pipeline; 12 – drain pipeline running from starting control unit of fuel regulating pump HP-30; 13 – pipeline for scavenging oil from front bearing of compressor low-pressure section; 14 – drain tank; 15 – [illegible] pipe connection [illegible] pipeline supplying air from deaerator to adapter; 17 – [illegible] centrifugal governor drain pipeline; 18 – pipeline for fuel supply to IGV actuator filter; 19 – fuel-regulating pump high-pressure outlet pipeline; 20 – pipeline supplying fuel to filter of air blow-off valve actuators; 21 – air filter; 22 – pipeline supplying air to ice detector [illegible]; 23 – pipeline supplying fuel from hydraulic decelerator to centrifugal governor [illegible]; 24 – fuel filter; 25 – fuel filter; 26 – air blow-off valve actuator pipeline; 27 – pipeline supplying extinguishant to fire-fighting system front spray ring; 28 – pipeline for fuel supply to IGV actuator; 29 – tee-piece; 30 – pipeline for air supply to solenoid-operated valve; 31 – pressure warning unit vent pipeline; 32 – breathing pipeline; 33 – pressure warning unit air supply pipeline; 34 – pipe connection; 35 – tee-piece for supplying fire extinguishant; 36 – IGV heating system pipeline; 37 – breathing pipeline; 38 – pipeline supplying fuel to IGV actuator; 39 – pipeline supplying fuel from IGV actuator to air blow-off valve actuator; 40 – pipeline supplying [illegible] fighting system front spray ring; 43 – pipe connection; 44 – [illegible] centrifugal governor drain pipe; 45 – pipeline draining oil from upper right-hand side drive gear box; 46 – pipeline for measuring fuel pressure at pump inlet; 47 – pipeline supplying fuel from hydraulic decelerator to centrifugal governor [illegible]; 48 – [illegible] breathing tube; 49 – pipeline supplying fuel to butterfly valve actuator; 50 – [illegible] air bleed pipeline; 51 – breathing pipeline; 52 – pipeline supplying fire extinguishant to rear spray ring; 53 – rear spray ring; 54 – large-slot manifold pipeline supplying fuel to burners 1, 3, 5, 7, 9, 11; 55 – small-slot [illegible] pipeline supplying fuel to burners [illegible]; 56 – large-slot manifold pipeline supplying fuel to burners 2, 4, 6, 8, 10, 12; 57 – small-slot manifold pipeline supplying fuel to burners 2, 4, 6, 8, 10, 12; 58 – pipeline supplying fire extinguishant into shafting tube; 59 – rear support breathing pipeline; 60 – pipe connection; 61 – breathing pipeline; 62 – [illegible] air bleed pipeline; 63 – small-slot fuel manifold; 64 – large-slot fuel manifold; 65 – pipeline supplying fuel to butterfly valve actuator; 66 – pipeline supplying fire extinguishing agent to rear spray ring; 67 – pipeline for draining fuel from small-slot and large-slot manifolds; 68 – pipeline supplying pressure P_c to air filter; 69 – pipeline supplying pressure P_c to fuel pump; 70 – ball bearing void oil scavenging pipeline; 71 – roller bearing void oil scavenging pipeline; 72 – pipeline supplying fuel to small-slot manifold; 73 – pipeline supplying fuel to large-slot manifold; 74 – pipeline scavenging oil from second turbine roller bearing; 75 – oil pressure gauge pipeline; 76 – panel for mounting pick-ups to measure engine operating conditions; 77 – pipeline for measuring fuel pressure in small-slot manifold; 78 – pipeline supplying oil to rear support; 79 – hose for [illegible]

the vicinity of the engine center of gravity, one bracket 7 being located on the upper part of the compressor low-pressure section front frame.

Engine lifting is allowed by two front sling brackets 6 and one rear sling bracket 5. Each engine is attached in the aircraft port side or starboard nacelle by means of four brackets 2 and one bracket 7. The remaining brackets are not used for attachment purposes. They are not shown in Fig.38.

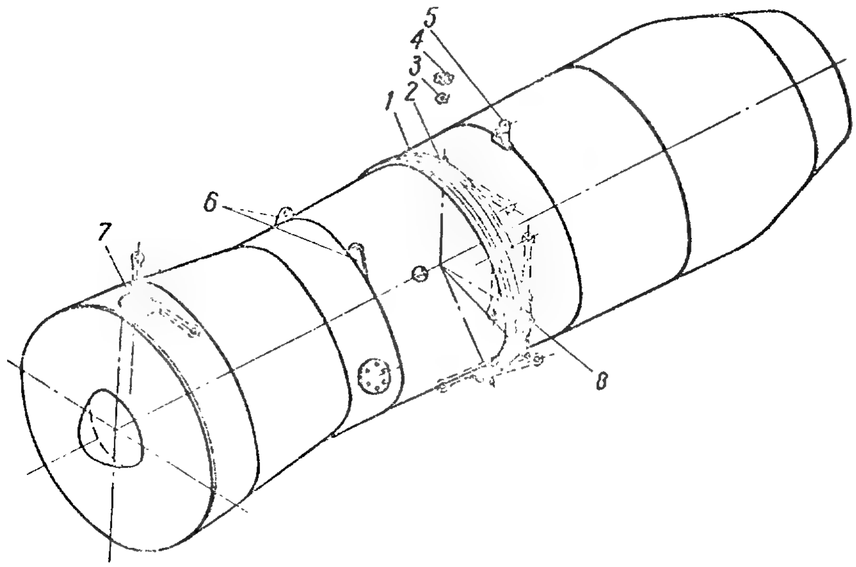

FIG. 38. DIAGRAM SHOWING UNITS FOR ENGINE ATTACHMENT IN AIRCRAFT
1 – engine hanger housing; 2 – brackets provided with taper trunnions; 3 – lock, 4 – nut, 5 – engine rear sling bracket; 6 – engine front sling bracket; 7 – engine front attachment bracket, 8 – twin attachment unit bracket.

The aircraft attachment units shown in the broken line are engaged with the bracket taper trunnions and are secured on them by means of nuts 4 locked by locks 3. Bracket 8 is coupled with the aircraft twin attachment unit, bracket 7 – with two attachment units provided in the aircraft. Remaining three brackets 2 are connected with their respective attachment units.

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OPERATING INSTRUCTIONS

Part II

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Chapter III

STARTING, WARMING-UP, RUNNING-UP AND SHUT-DOWN OF ENGINE

I. PREPARATION OF ENGINE FOR STARTING

Preparation of the engine for starting includes the following operations:

I. Remove the blanking covers from the air intake and exhaust unit.

2. Make sure to see that there are no stray objects or injuries in the air intake duct or in the exhaust unit. Inspect visible blades and vanes of the compressor first spool and of the second turbine, turn the l.p. rotor manually by the blades of the compressor first stage or the turbine fourth stage.

3. Open the cowl covers and the inspection hatches to make sure that:

(a) the pipelines of the fuel, lubricating oil, hydraulic, air, fire-fighting systems, as well as the lines of the electric equipment system are free of external injuries and are securely locked;

(b) there are no foreign objects inside the engine nacelle.

4. Check the oil and fuel tanks for content levels; replenish oil and fuel, if necessary. See that the tank filler plugs are properly secured. With the lubricating system properly primed the oil tank must contain at least 25 lit of oil. Minimum amount of oil in the tank ensuring normal operation of the engine should not be less than 12 lit. Prior to filling the fuel and oil tanks, check to see that certificates are available with the data pertaining to the quality of the fuel and oil used.

The analysis data should agree with the respective USSR State Standards:

GOST 10227-62 for fuel Grades T-I and TC-I, GOST 6457-53 for Grade MK-8 oil, MPTYI[illegible] No. 12-62 for Grade MK-8П oil, [illegible] Y-38-1-164-65 for Grade ВНИИНП-50-I-4Ф oil. It is allowed to blend fuels T-I and TC-I, or mineral oils MK-8 and MK-8П in any proportion. Do not blend Grade MK-8 and MK-8П oil with Grade ВНИИ НП-50-I-4Ф oil. Prior to filling the oil tank with Grade ВНИИ НП-50-I-4Ф oil after running the engine on mineral oils, or vice versa, it is imperative to flush the engine lubricating system with oil to be filled anew, as instructed in Chapter XII.

Fuels and oils of foreign origin should comply with the requirements of the USSR State Standards. Substitution of fuels and oils used in the engine by fuels and oils of foreign grades should be done in compliance with the following table:

<u>Fuels</u>

Nos.	USSR	Other countries		
		Mark	Specification number	Country
I.	T -I, TC-I by GOST 10227-62	Type A-I Avtur-50 PL-4 JP-5 (Avkat) Type 1 PT-2 PR-9025 Avtur-50	D1655/A3T Air-3405/B TPA-75-005-64 [illegible] 3GP-23e [illegible] TY THN-12991 DERD-2494	U S A France Czechoslovakia Japan Canada Poland GDR Great Britain

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I	II	3	4	5
	Oils			
2.	МК-8, МК-8п by GOST 6457-66 (mineral)	Turbooil-3 Turbooil-3 Turbooil-2 Turbooil-2	D.Eng.RD-2490 Air-3515 A Mil-O-6081 B 3 - GP -901	Great Britain France U S A Canada
3.	Масло ВНИИ НП-50-1-4Ф by МРТУ-38-1-164-65 (synthetic)	Turbooil-300 Turbooil-300 Turbooil-300 Turbooil-750	Mil-L-7808C;F Air -3513 3 - GP -904a D.Eng.RD-2487	U S A France Canada Great Britain

The above tabulated grades of fuel produced in foreign countries may be used in case the aircraft fuel tanks are not to be cooled below minus 45°C in service.

5. Check the engine control system for proper operation . The engine control lever should be capable of free movement. Check to see that the positions of the engine control lever at the idling, TAKE-OFF and CUT-OFF stops are in agreement with the respective positions of the carrier index of the HP-30 fuel regulating pump. Set the engine control lever in the CUT-OFF (STOP) position.

6. Refer to the voltmeter to check the aircraft storage battery,making sure it is properly charged. Otherwise connect a ground power supply source.

7. Supply voltage to the instruments and automatic control equipment and check voltage in the mains,which should amount to not less than 27V ± 10% as read off the voltmeter mounted in the aircraft crew cabin.

8. Open the fuel shut-off valve and switch on the aircraft booster pump.

9. Inspect the joints of the fuel and oil pipelines and units for leakage. No fuel or oil leakage is allowed.

Before motoring over the engine or carrying out a "false"start,bleed air from fuel regulating pump HP-30 and centifugal governor ЦР-1Б by the use of a special appliance, in case the aircraft fuel system has been emptied.

10. Check the operation of engine vibration measuring equipment ИВ-200Е,for which purpose warm up the equipment for 5 minutes and press pushbutton TEST (КОНТРОЛЬ). As a result,two indicating lamps must come on and the indicator pointers should displace to indicate any scale division within the range of from 75 to 100 mm/sec.

If the indicator pointer deviates by more than 100 mm/sec (moves beyond the scale limit),check to see that the pick-up unit circuit is intact.

If the pointer stops below the 75 mm/sec division,pay attention first to the condition of the amplifier respective channel.

After cutting out the vibration equipment,make certain to see that the indicator pointers are set properly at the initial positions and indicate zero. Make use of the indicator adjusting screws to adjust the initial position of the pointers,if necessary.

11. Actuate the TEST button of the ДПП-6 fire detectors of the fire-fighting system to see that the ENGINE ON FIRE (ПОЖАР в ДВИГАТЕЛЕ) light flashes up testifying that the ДПП-6 fire detectors are in proper condition. Disengage the TEST button.

Notes: 1. If the engine is not to be started immediately after preparation, it is necessary to cut out the aircraft fuel system booster pump,close

[redacted]

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the shut-off valve and deenergize the instruments and automatic control units.

2. In case the fuel or lubricating system has been emptied for some reason or other, or the aircraft has been out of service for more than 5 days, do not fail before starting the engine to motor the engine over or carry out a "false" start as specified in Chapter XI.

2. ENGINE STARTING

To start the engine, use the following procedure:

1. Supply voltage to the instruments and automatic control units.

2. Turn on the master switch of starting control unit АПД-19ВЛ (series II).

3. Set switch GROUND – AIR of automatic control unit АПД-19ВЛ (series II) in the GROUND position.

4. Supply voltage to amplifier УРТ-19А-2Т incorporated in the jet pipe overtemperature control system, type ИРТ-35.

5. Set the function switches of automatic control unit АПД-19ВЛ (series II), in position ENGINE STARTING (ЗАПУСК ДВИГАТЕЛЯ).

6. Open the fuel shut-off valve and switch on the aircraft fuel booster pump.

7. Give out the starting signal.

8. Press the engine start button and keep it depressed for 1 to 2 sec.

9. After the button is pressed and the engine h.p. rotor is spinned up to 800 – 1000 rpm (7 – 8.5%) move the engine control lever to the IDLE position. Further acceleration of the engine to the idling speed takes place automatically within not more than 120 sec.

Note: In case of aborted starts do not fail to check the voltage and amperage across the starter-generator terminals at the compressor h.p. rotor speed n_2 = 3300 rpm (25%). The parameters should be within the following limits:

When starting is performed from external power sources ..	350 A ± 15% 40 – 50 V
When starting is accomplished from internal power sources	250 A ± 15% 32 – 38 V
When starting is performed from running engine generator	350 A ± 15% 38 – 40 V

10. Make sure the starter-generator is disengaged by the ЦР-2В centrifugal governor after the high-pressure rotor gains a speed of 4500 ± 200 rpm (37 – 40%) or by automatic starting control unit АПД-19ВЛ (series II) 45 – 50 sec after the start button has been pressed, if the engine has not gained a speed of 4500 ± 200 rpm (37 – 40%).

CAUTION. (a) Do not adjust fuel flow during starting manually by changing the position of the engine control lever;

(b) Exhaust gas temperature during engine starting must not exceed 620°C. The engine is not allowed to run at 620°C for more than 4 sec;

(c) In case the starter-generator fails to be disengaged after the high-pressure rotor gains a speed of 4700 rpm (40%) or after running for 50 sec, disengage it manually by depressing the ABORT (ПРЕКРАЩЕНИЕ ЗАПУСКА) button;

(d) When starting the engine from on-board power sources, disengage vibration measuring equipment ИВ-200Е for the period of starting.

11. Engine starting is discontinued in the following cases:

(a) if turbine outlet gas temperature exceeds 620°C or is kept at 620°C for more than 4 sec;

(b) if the engine is petering out in an attempt to gain idling speed;

(c) if the oil pressure at the inlet to the engine does not rise;

(d) if the chip-detecting filter sends a signal on detecting chips in the oil.

(e) Whenever any other malfunctioning is detected in operation of the engine or its accessory units during the starting procedure.

Starting should be discontinued by setting the engine control lever in the CUT-OFF position and by disengaging the starter-generator by means of the ABORT button, in case the starter-generator has failed to be disengaged automatically.

Notes: (a) Repeated starting of the engine is allowed only after stopping the high-pressure rotor, finding out and eliminating the cause of the abnormal start;

(b) Each engagement of the starter-generators for carrying out "false" or normal starts as well as for motoring the engine over should be followed by an interval of at least 5 min for cooling purposes; after five successive starting cycles an interval of not less than 30 min should follow to allow complete cooling of the starting system units.

12. Inspect the engine for fuel and oil leakage, eliminate detected troubles.

3. ENGINE WARMING-UP

Prior to accelerating the engine to maximum take-off rating after starting do not fail to warm up the engine, proceeding as follows:

(a) run the engine at idling speed for not less than 2 min;

(b) gradually advance the engine control lever to set 0.7 normal rating (87.0 - 88.5%) and warm up the engine for at least 1 minute at that rating.

With the engine properly warmed up, it is permissible to set the engine at maximum take-off or any other rating, as well as to accelerate the engine to any working speed.

When warming up the engine, check the engine operating parameters and make certain the engine runs properly.

1. Check to see that the engine idling speed is in compliance with the graph in Fig.40. At P_H = 760 mm Hg and t_H = 15°C the compressor high-pressure rotor speed must be within 7200 ± 100 rpm (61 - 62.5%). At any other atmospheric conditions the idling speed should comply to the graph presented in Fig.40.

2. With the engine running idle, the instruments should give the following readings:

(a) oil pressure at the engine inlet must be not less than 2.5 kg/sq.cm;

(b) turbine outlet gas temperature should not exceed 360°C;

(c) fuel pressure in the primary fuel manifold should be about 25 kg/sq.cm.

Note: Should any abnormalities be detected in engine operation or instrument readings, shut-down the engine for finding out and eliminating the defects.
Final checking of idling speed value for compliance with the Specifications should be performed after trying out the engine at all the ratings (when warmed up).

CAUTION. Never run the engine with the engine control lever set below the IDLE speed position.

3. As the engine speed approaches 0.7 normal rating, observe the indicating light to note the speed at which the IGVs have turned from - 10 deg to zero degree position; the speed must be within 9400^{+125}_{-175} rpm (79.0 - 81.5%). Simultaneously with the changing-over of the position of the IGVs, the air blow-off shutters get closed and the air bleed control butterfly valves change over their position supplying hot

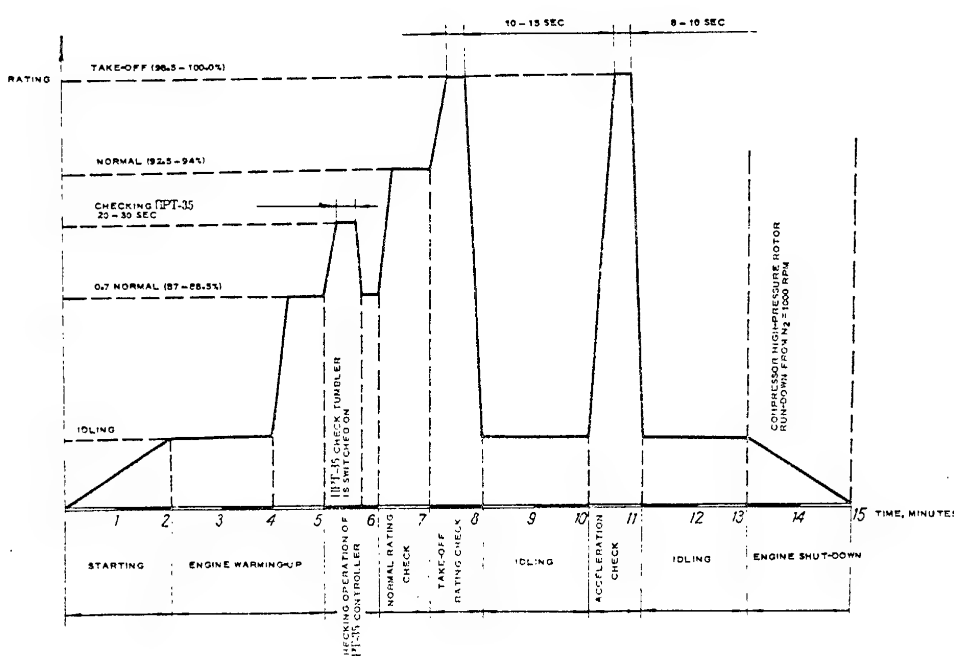

FIG. 39. ENGINE WARMING-UP AND TRYING CHART

air from the 5th stage instead of the 10th stage of the compressor high-pressure section for cooling the compressor low-pressure IGV assembly and the air intake.

At the moment the air blow-off shutters of the compressor h.p. section get closed, a short-time rise in fuel pressure before fuel regulating pump HP-30 takes place.

4. Refer to the pointer of the indicator to make sure the ИВ-200Е vibration measuring equipment functions properly and the engine vibrations do not exceed the permissible critical limit.

The engine vibration speed at any operating rating should not exceed 50 mm/sec (if the vibration speed is more than 50 ± 10 mm/sec, a warning light comes on).

In case the vibration speed exceeds the maximum permissible value, it is necessary to slow down the engine to the idling speed and shut it down after cooling preliminarily. The possibility of further use of the engine should be decided upon together with the representative of the engine Manufacturing plant.

4. ENGINE RUNNING-UP

1. The engine must be checked for operation in the following cases:

(a) after postflight maintenance;

(b) during scheduled routine maintenance;

(c) in cases set forth in Chapters IX and XI of these Instructions.

2. The engine must be tried out in compliance with the Chart presented in Fig.39, observing the following:

(a) prior to trying out the engine, prepare the data relating to rpm values and gas temperature characteristics for various ratings. Make use of the Charts in Fig.40, 41, 42, taking into account the atmospheric conditions prevailing at the time of engine starting;

(b) warm up the engine;

(c) having warmed up the engine at 0.7 normal rating, switch on the tumbler for checking the ПРТ-35 overtemperature control system and smoothly advance the engine control lever to the TAKE-OFF position. The overtemperature control system must operate, if the turbine outlet gas temperature comes up to a value 110 ± 10°C less than the gas temperature preset by the proportional potentiometer of the УРТ-19А-2Т overtemperature amplifier.

The engine operating time at the point ПРТ TEST (КОНТРОЛЬ ПРТ) must be within 20 - 30 sec. The checkup over, gradually retard the engine control lever to bring the engine to 0.7 normal rating (87.0 - 88.5%), switch off the tumbler used for checking the ПРТ-35 overtemperature control system, then accelerate the engine to normal rating (92.5 - 94.0%). This should be done within 10 - 20 sec. Run the engine at the normal rating for one minute.

Accelerate the engine to maximum take-off rating and run it for 10 or 15 sec at that rating. When running the engine at maximum take-off or normal rating, check the indications of the instruments registering the following operating parameters of the engine: oil pressure and temperature, compressor h.p. rotor speed, turbine outlet gas temperature, and fuel pressure in the burner small-slot manifold. The indications should be in compliance with the specified data. While running the engine at maximum take-off rating, check to see that the actual engine speed and turbine outlet gas temperature agree with the respective values presented in the Charts of Figs 41 and 42.

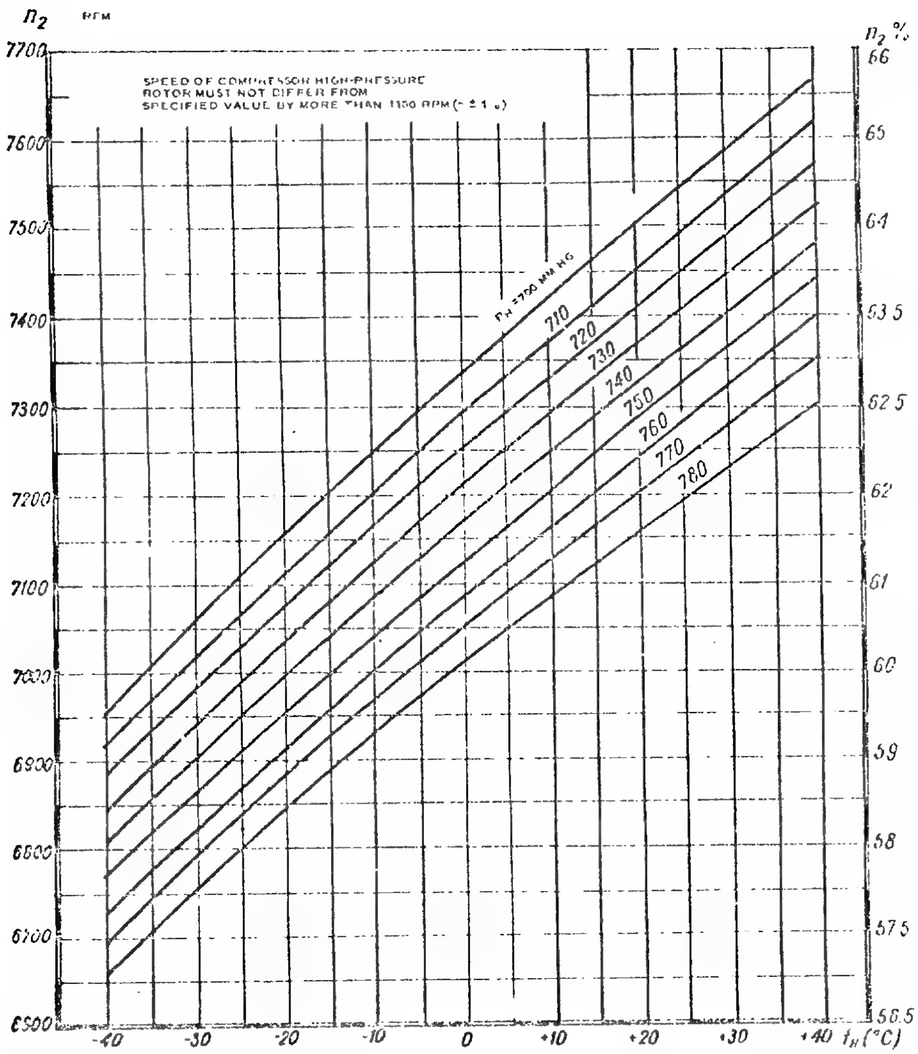

FIG. 40. VARIATION OF COMPRESSOR HIGH-PRESSURE ROTOR SPEED AT GROUND IDLING RATING VERSUS ATMOSPHERIC CONDITIONS

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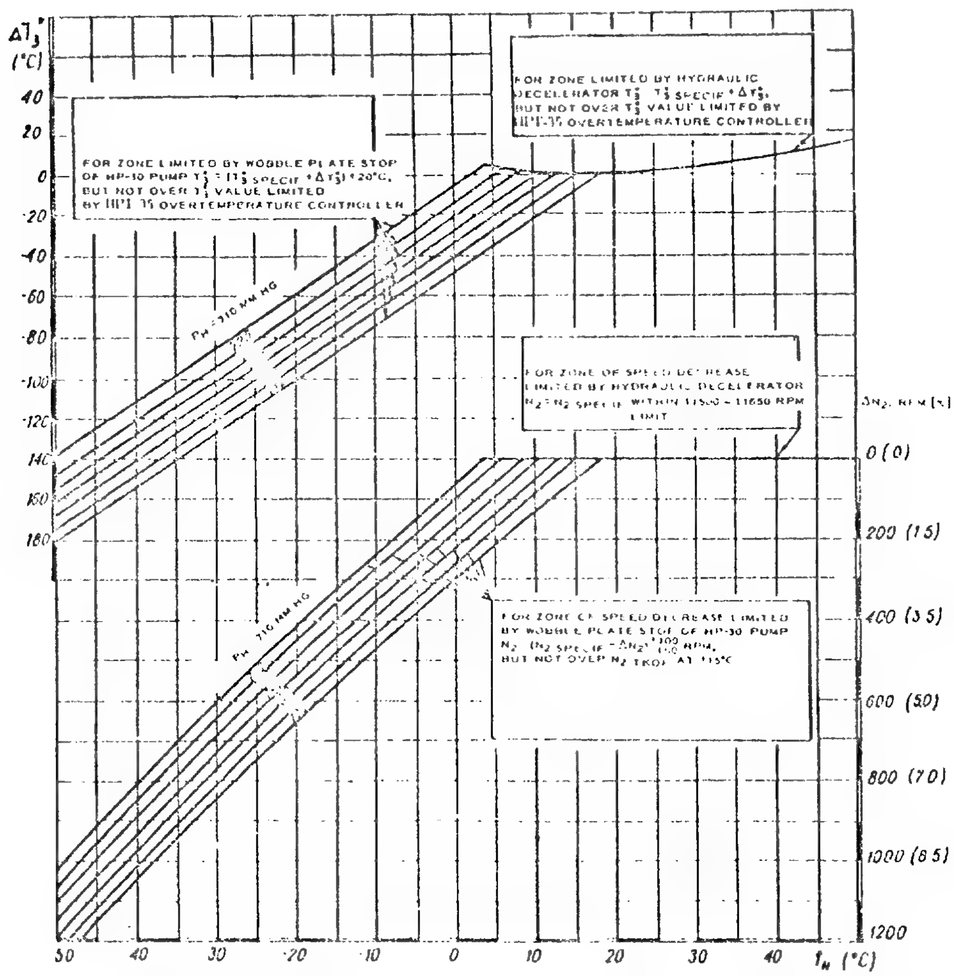

FIG. 41. MAXIMUM PERMISSIBLE TURBINE OUTLET GAS TEMPERATURE AND VARIATIONS IN COMPRESSOR HIGH-PRESSURE ROTOR SPEED AT MAXIMUM TAKE-OFF RATING ON GROUND, DEPENDING ON ATMOSPHERIC CONDITIONS

25X1

(d) vibration speed at all the ratings under consideration should not exceed 50 mm/sec;

(e) upon checking the engine operation at maximum take-off rating slow the engine down to idling speed. Run the engine at idle for two minutes and check to see that the compressor h.p. rotor speed corresponds to the value specified by the Chart in Fig.40.

When bringing the engine to idling speed, refer to the indicating light to note the speed at which the compressor h.p. IGVs change over their position from zero to - 10 deg position and the speed at which the air blow-off shutters aft of the 4th and 5th stages of the compressor h.p. section open. The speed should be within 9100 ± 100 rpm (77.0 - 79.0%). Opening of the air flow-off shutters is associated with a notable pressure drop of 4 or 6 kg/sq.cm in the primary fuel manifold with subsequent increase of pressure to the original value.

(f) having ascertained that the engine operates normally at all of the ratings, check engine acceleration time from idling speed to maximum take-off speed. Before doing this, do not fail to operate the engine at idle for not less than two minutes. Perform the acceleration check by shifting the engine control lever from IDLE to MAXIMUM TAKE-OFF position. Move the engine control lever smoothly, within 1 to 1.5 sec. After the engine has been brought to maximum take-off rating, operate it for 8 or 10 sec and then retard the engine control lever to IDLE within 1 or 1.5 sec.

The acceleration time from idle to maximum take-off rating should be not more than 15 sec and not less than 10 sec. Acceleration time must be counted from the moment the engine control lever starts moving to the moment the compressor h.p. rotor speed comes up to a value 180 rpm (1.5%) less than the maximum take-off rpm at the given atmospheric conditions.

Note: Throughout starting and during rapid deceleration of the engine from any rating to idle rpm, the indicating light of the ЛО-202М ice detector circuit may flicker on and off.

At an ambient air temperature of below +15°C maximum take-off rpm during acceleration checks are assumed to be equal to measured rpm at the considered ambient temperature, which is associated with the limitation of maximum fuel flow The compressor h.p. rotor speed and turbine outlet gas temperature should fall within the limits indicated in Fig.41.

The engine should run without pops and excessive vibrations within the entire operating range both in acceleration and deceleration.

CAUTION. (a) air bleed for aircraft needs is allowed at the engine rpm not exceeding 95.0%.

Bleeding of air for heating the IGVs, nose bullet and air intake is permissible at maximum take-off rating, bearing in mind that the engine should not operate over two minutes at rpm higher than 95%;

(b) while checking the engine operation at maximum take-off rating with the heating air bleed system cut on, supplying hot air to the IGVs, nose bullet and air intake, and in fast acceleration of the engine from idle to maximum take-off rpm, the turbine outlet gas temperature may rise for a short-time period up to a temperature limited by the НРТ-35 overtemperature control system; at subzero ambient temperatures the turbine outlet gas temperature may rise by 20°C above that permissible in accordance with the Chart in Fig.41, but not in excess of the value limited by the НРТ-35 system.

3. The engine is put into service with the following parameters preadjusted:

(a) compressor high-pressure rotor speed at maximum take-off rating adjusted by the hydraulic decelerator stop incorporated in fuel regulating pump НР-30;

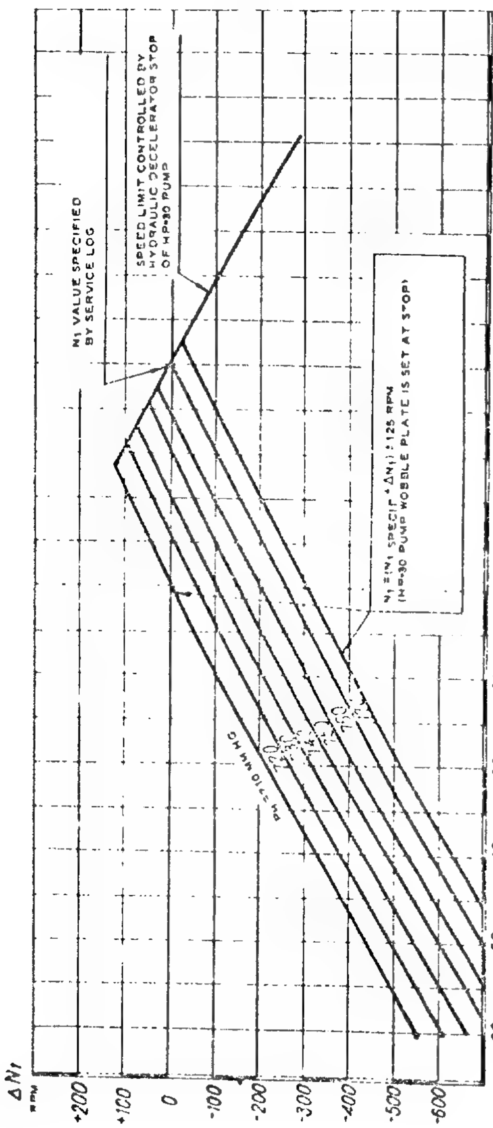

FIG. 42. MAXIMUM PERMISSIBLE SPEED OF COMPRESSOR LOW-PRESSURE ROTOR ON GROUND VERSUS ATMOSPHERIC CONDITIONS

(b) maximum fuel flow adjusted by the respective stop of fuel regulating pump HP-30;

(c) compressor low-pressure rotor maximum speed adjusted by the screw of centrifugal governor HP-1B;

(d) turbine outlet gas temperature limited by the HPT-35 system at maximum take-off rating;

(e) speed limit controlled by the HPT-35 system.

If it is required to make an adjustment of the above listed operating parameters of the engine, follow the instructions set forth in the respective sections of Chapter VIII.

4. When the indicator light of the chip-detecting filter system comes on, shut the engine down as advised in Section 5 below.

5. ENGINE SHUT-DOWN

To shut down the engine from any speed, proceed as follows:

1. Slowly retard the engine control lever to the IDLE position. Run the engine for at least 2 minutes at the idling speed. Before stopping the engine immediately after starting it is imperative to operate the engine at idling speed for not less than one minute in order to purge the engine drain system.

2. Switch off the YPT-19A-2T amplifier of the HPT-35 over-temperature control system.

3. To stop the engine, move the control lever to the CUT-OFF position.

4. When the engine rotors spin by inertia, make sure that no foreign noise is heard within the engine, that the rotors revolve smoothly; measure the run-down time of the compressor low-pressure and high-pressure rotors from a speed of 1000 rpm (8.5%) of the compressor high-pressure rotor.

The run-down time should be:

(a) not less than 90 sec for the low-pressure rotor;

(b) not less than 50 sec for the high-pressure rotor.

Note: When measuring the engine rotor run-down time, observe the turbine 4th stage to detect the moment the low-pressure rotor stops rotating and listen to the starter-generator ratched-tooth clutch to detect the moment the high-pressure rotor stops rotating. The engine run-down time must be measured when checking the engine for operation on the ground.

5. After the compressor high-pressure rotor has come to a standstill, cut off the fuel booster pump and close the fuel shut-off valve.

CAUTION. In the event of stopping the engine by closing the fuel shut-off valve, further use of the fuel system units must be decided upon together with the representative of the engine Manufacturing plant.

6. EMERGENCY SHUT-DOWN OF ENGINE

In case of emergency, engine shut-down is accomplished by quickly shifting the engine control lever to the CUT-OFF position from any operating rating.

This procedure should be resorted to on the following occasions:

(a) when an abrupt drop in oil pressure at the engine inlet is experienced;

(b) if fuel or oil leakage is detected;

(c) in case an abrupt increase in turbine outlet gas temperature occurs;

[redacted]

(d) if flame appears at the exhaust unit outlet or heavy sparking from the exhaust unit is observed;

(e) if engine vibration sets in or vibration speed rises to 90 mm/sec;

(f) in case of icing of the engine air intake duct;

(g) in the event of fire;

(h) if foreign noise is detected within the engine;

(j) in case of an abrupt increase in oil temperature at the engine inlet at a steady rating;

(i) if the blow-off shutters do not open at a speed below n_2 = 8200 rpm (70%) with the engine control lever swiftly retarded.

After emergency stoppage of the engine, find out the cause of trouble and its effect on the engine condition; further use of the engine should be decided upon together with the representative of the Manufacturer.

If the engine emergency shut-down has been performed on some other reasons not relating to the engine (in case the aircraft starts moving spontaneously, inadvertent stoppage of the engine, etc.), as well as in the event of minor defects (minute leaks of oil or fuel), start the engine not later than 15 minutes after stopping, run it at idle rpm for 2 min, then operate the engine at 0.7 normal rating for 1 minute and proceed with the previous task or stop the engine as instructed in Section 5. This done, consult the representative of the Manufacturing plant as to further use of the engine.

7. OPERATIONS TO BE CARRIED OUT AFTER ENGINE TRIAL

1. Make sure there is no leakage of oil or fuel. Eliminate leakage, if any.

2. Examine the engine air intake duct, the IGVs, the compressor l.p. section blades, the turbine 4th stage nozzle vanes and rotor blades within the vision field. Inspect the exhaust unit. No damage is permissible.

3. Examine the engine attachment units and their locking devices, as well as the attachment and locking of all the external engine accessories and pipelines.

4. Upon inspection do not fail to close the engine intake and exhaust ducts with their respective blank covers.

The engine exhaust duct should not be closed earlier than 10 or 15 minutes upon stopping the engine.

OPERATION OF ENGINE IN FLIGHT

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Chapter IV

OPERATION OF ENGINE IN FLIGHT

1. TAXIING, TAKE-OFF, AND CLIMBING

1. After starting, warm up the engine by running it at idling speed for not less than 2 minutes, at 0.7 normal rating (87.0 - 88.5%) for not less than one minute, then taxiing is allowed.

Note: While the engine is being accelerated to and run at 0.7 normal rating, the aircraft may be taxied to the take-off start line.

2. During checking the engine operation before flight and in flight, see to it that the engine operating parameters (speed, turbine outlet gas temperature, oil pressure and vibration overloads) are not in excess of the values specified in the section "Basic Data".

3. Aircraft taxiing may be accomplished at any of the ratings exclusive of 77.0 - 81.5 per cent rating, when air blow-off shutter closing or opening takes place, or the IGVs of the compressor high-pressure section turn from one to the other position. It is not recommended to run the engine at this rating. While taxiing the aircraft, see that instrument readings agree with the values specified for the given ratings.

4. Just before taking-off, check engine operating parameters to make sure they conform to the values specified for maximum take-off rating.

5. Bear in mind that at the outside air temperature below +15°C (when the engine maximum fuel flow is restricted at P_H = 760 mm Hg), the compressor high-pressure rotor speed will reduce by 180 or 200 rpm (1.5 - 2%) and turbine outlet gas temperature will reduce by 20 or 25°C per every 10°C of ambient air temperature drop relative to the above value at maximum take-off rating.

The compressor high-pressure rotor speed at 0.7 and 0.88 normal ratings as well as at the normal rating on the ground at an ambient air temperature of below +15°C and at constant thrust are taken in accordance with the Chart in Fig.43.

In case the engine operating parameters do not agree with the specified values, perform adjustment operations in accordance with the Section "Adjustment of Engine Accessory Units".

Note: When the engine is brought to maximum take-off rating with the HPT-35 overtemperature control system cut off, a short-time rise in the exhaust gas temperature aft of the turbine up to 630°C is permissible.

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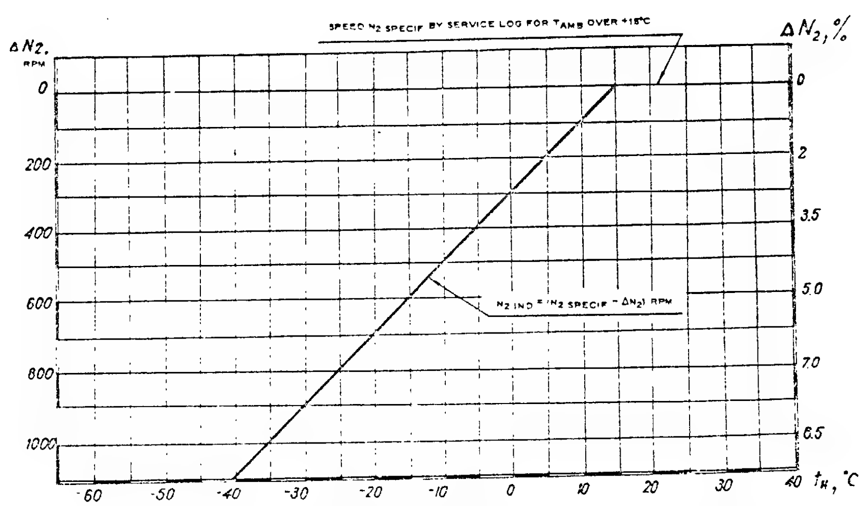

FIG. 43. CORRECTION TO COMPRESSOR HIGH-PRESSURE ROTOR SPEED AT NORMAL AND CRUISING RATINGS ON GROUND, DEPENDING ON OUTSIDE AIR TEMPERATURE AT CONSTANT THRUST

6. The engine should not run continuously at maximum take-off rating for more than 5 minutes. After that decelerate the engine to normal or less arduous rating.

CAUTION. 1. Subsequent acceleration of the engine to maximum take-off rating is allowed not earlier than after 5 min of operation at normal or less arduous rating.
2. Never bleed air into the wing and fin deicing systems and into the aircraft cabin (for pressurizing) with the engine running at a speed exceeding 95%.
Compressed air may be bled at maximum take-off rating for not over 2 minutes at an altitude not higher than 2 km for heating the engine IGVs, nose bullet and air intake duct only.

7. With the engine control lever fixed within the range of from idle to the beginning of engine automatic operation (up to n_2 = 9700 ± 50 rpm or 82.5 - 83.5 per cent), any reduction in flight altitude (gliding) or increase in flight speed will result in a reduction of the compressor low-pressure and high-pressure rotor rpm.

At any speed higher than the speed corresponding to the beginning of automatic operation of the engine, with the engine control lever fixed and flight altitude and speed varying, the compressor high-pressure rotor speed is kept constant, whereas the compressor low-pressure rpm vary. As the flight altitude rises and the flight speed drops, the compressor low-pressure rpm increase owing to the reduction of ambient air temperature at the engine inlet. When the engine runs with the wobble plate of the HP-30 fuel regulating pump set at the maximum flow stop, any increase in flight altitude and reduction in flight speed will result in an increase of the high-pressure and low-pressure rotor speeds. As the compressor low-pressure rotor speed comes up to its preset limit, the speed remains constant irrespective of altitude increase or flight speed reduction; the compressor high-pressure rotor speed reduces in that case. Approximate variations in speed of compressor low-pressure and high-pressure rotors at take-off rating versus flight altitude and ambient air temperature are shown by the Charts in Fig.44.

2. LEVEL FLIGHT

1. Level flight may be performed at any engine rating exclusive of 77.0 - 81.5 per cent rating, associated with closing and opening of the air blow-off shutters or turning of the IGVs of the compressor high-pressure section.

2. Engine operating time in flight at any rating up to normal rating is not limited within the specified duration of engine operation within the entire service life (see Chapter I).

3. Engine acceleration in flight may be accomplished from any rating, idling rating included. Turbine outlet gas temperature should not rise in excess of 630°C in that case.

4. Until sufficient experience is obtained, watch closely the variation in vibration speed and engine parameters (rpm, turbine outlet gas temperature, oil pressure and temperature), if the indicating light of the HB-200E vibration measuring equipment comes on (the vibration speed exceeds 50 mm/sec). In case the engine operating parameters do not vary materially with the vibration speed rising (above 50 mm/sec), bring the engine to a minimum possible rating to maintain the required flight conditions, and take measures to stop the engine as soon as possible.

Should the vibration speed come to 90 mm/sec, or the engine operating parameters vary, shut down the engine at once.

Upon landing the aircraft and stopping the engine check vibration measuring equipment ИВ-200Е, and measure engine vibrations with the use of the АВ-43 equipment. Further use of the engine is decided upon the results of the engine inspection and the vibration measurements.

5. Immediately stop the engine, if the warning light in the chip-detecting filter circuit comes on. Upon landing the aircraft examine the chip-detecting filter and filter МФО-30 to decide whether the engine is fit for further service.

3. ENGINE SHUT-DOWN IN FLIGHT

To shut the engine down in flight, use the following procedure:

1. Shift the engine control lever to the IDLE position and run the engine at this speed for not less than 1 min.

2. Set the engine control lever in the CUT-OFF position.

3. To guard the pumping unit of the НР-30 fuel regulating pump against failure, do not close the fuel shut-off valve, if no emergency situation is involved.

4. Emergency shut-down of the engine is accomplished on occasions referred to in Section 6, Chapter III, except Item (f), by shifting the engine control lever to the CUT-OFF position.

4. RELIGHTING ENGINE IN FLIGHT

1. Engine relight in flight is performed at a high-pressure rotor windmilling speed of not less than 1200 rpm (10.5%) to an altitude of 4000 m and not less than 1500 rpm (13.0%) at an altitude of over 4000 m. To relight the engine, press the RELIGHT button for 1 or 2 sec. As a result, the engine ignition system is cut in via starting control unit АПД-19БМ (series II) and operates for 60 sec.

2. 5 to 8 sec after pressing the RELIGHT button, set the engine control lever in the IDLE position, which will cause a pressure rise in the primary fuel manifold, ignition of air-fuel mixture in the combustion chamber, and an automatic acceleration of the engine to idle rpm.

With the engine control lever set in the IDLE position, engine rpm will be in direct proportion to the altitude of flight. Idling rpm will increase approximately by 200 - 400 rpm (1.5 - 3.5%) per every 1000 m increase in flight altitude.

3. Engine acceleration to the required rating is allowed not earlier than after 1 min running at idling speed.

4. In the event of an abnormal start (60 sec after pressing the RELIGHT button) or abortive starting, set the engine control lever in the CUT OFF position and blow the engine at windmilling speed for 30 sec.

5. After two abortive startings it is recommended to increase windmilling speed (prior to attempting the next relighting) by increasing the flight speed or decreasing the altitude of flight.

<u>Note</u>: (a) The engine starting control equipment provides for manual switching of ignition in flight in addition to switching ignition automatically. To switch on ignition manually, press the relight button and keep it pressed until fuel ignition takes place, but do not keep it depressed for more than 60 sec;

(b) Normal engine starting is guaranteed to an altitude of up to 7000 m;

(c) When the engine is being started in flight, turbine outlet gas temperature is allowed to rise to 620°C for not over 4 sec;

(d) Do not start the engine in flight after stopping it by means of closing the fuel shut-off valve.

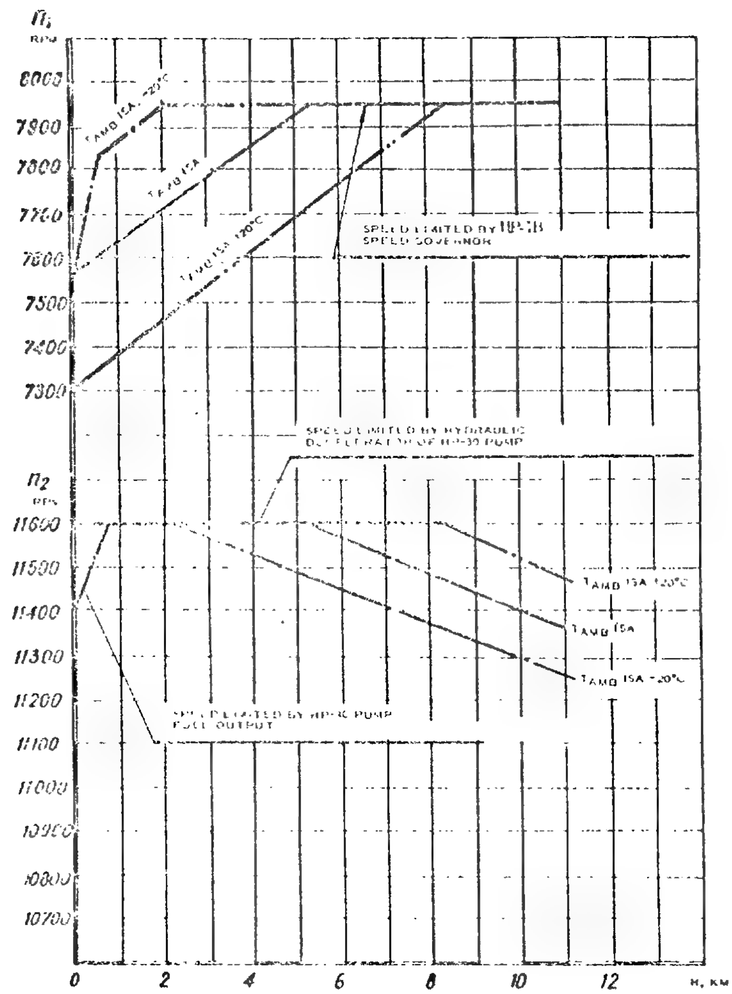

FIG. 41. VARIATIONS IN SPEED OF COMPRESSOR LOW- AND HIGH-PRESSURE ROTORS DEPENDING ON FLIGHT ALTITUDE AND AMBIENT AIR TEMPERATURE WITH ENGINES RUNNING AT TAKE-OFF RATING LIMITED BY CENTRIFUGAL GOVERNOR HP-1B. AIRCRAFT FLYING SPEED CORRESPONDS TO $M_f = 0.55$

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5. ELIMINATING FIRE ON ENGINE

In case the engine sets aflame, proceed in the following manner:

1. Immediately stop the engine and close the fuel shut-off valve.

2. Cut off air supply for pressurizing the cabin from the affected engine.

3. Proceed to fire extinguishing in compliance with the recommendations on fire-fighting, contained in the aircraft Operating Instructions.

<u>Note</u>: After extinguishing the fire on the engine, consult the representative of the Manufacturing plant as to further use of the engine, if the engine and its accessories have been exposed to high temperature.

4. Should the fire-extinguishing bottles be discharged into the engine not affected with fire, and fire extinguishant Freon 114B-2 get into the oil-contacted surfaces of the by-pass duct entry housing and the cavities of the compressor and turbine rotor bearing supports, it is imperative to do the following:

(a) within 3 hours after fire extinguishant Freon 114B-2 gets into the engine, drain oil completely from the shaft tube, second turbine rear support, by-pass duct entry housing, fuel-cooled oil cooler (unit 62) and oil tank. Remove and wash with kerosene oil filter MФO-30 and the chip-detecting filter incorporated in centrifugal deaerator MФO-6C-30;

(b) fill the lubricating oil system with fresh oil heated to a temperature of 50 or 60°C, then motor the engine over;

(c) start the engine and run it at idle speed for 5 min and then at 0.7 normal rating for 5 min;

(d) shut down the engine and drain oil again from the engine assemblies, the oil cooler and the tank. Examine and wash in kerosene oil filter MФC-30 and the chip-detecting filter;

(e) fill the lubricating oil system with fresh oil;

(f) start the engine and run it at idling speed for 5 min, then at 0.7 normal rating for 5 min, and at normal rating for 5 min;

(g) shut down the engine, inspect engine oil filter MФC-30 and the chip-detecting filter.

The engine is fit for further service, if no defects are detected. Prior to putting the engine into service it is necessary to replace connection 30-03-893 for fire extinguishant supply into the engine, having installed such a connection with a sound diaphragm.

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Chapter V

PECULIARITIES OF ENGINE OPERATION IN WINTER

1. Do not start the engine, in case ice is detected on the air intake components. Prior to starting the engine at zero and subzero ambient air temperatures check the second turbine rotor for proper rotation by hand. In case the rotor fails to rotate, deice the blades of the compressor low-pressure rotor, sticking to the casing by blowing the compressor with hot air at a temperature of not over 80°C.

2. Engine starting under an ambient air temperature of below +5°C and at increased air humidity as well as in case of comming on the ice warning light must be carried out after switching on the deicing systems of the aircraft and engine air intake ducts.

3. If lubricating oil МК-8 or МК-8П is used in the engine at an outside air temperature of - 30°C or lower with the aircraft parked for more than two hours, the engine starting should be preceded by supplying hot air at a temperature of not over 80°C from airfield heating means to heat fuel regulating pump НР-30 (where the starting fuel control unit is located), oil cooling adapter, lower portion of the compressor low-pressure section IGV assembly, fuel-cooled oil cooler (unit 62) and oil tank for at least 20 minutes until oil temperature at the engine inlet increases to +10°C.

If oil ВНИИ НП-50-1-4Ф is used in the engine, the above listed units and accessories should be heated before starting the engine, in case the outside air temperature is -40°C or lower.

4. If an outside air temperature is -40°C or lower and the aircraft is to be parked for more than one hour, do the following:

(a) drain lubricating oil from the engine and the tank after stopping the engine;

(b) prior to starting the engine, heat with hot air at a temperature of 80°C (maximum) the engine units and accessories as instructed under Item 3, then fill the engine lubricating oil system with fresh oil heated to a temperature of 60 - 80°C;

(c) before starting the engine, do not fail to motor it over.

Note: It is allowed to heat oil for 30 minutes as advised in Item 3 instead of draining oil from the system and filling it with heated oil.

5. At sea level and outside air temperatures below +15°C, turbine outlet gas temperature and the speed of the compressor high-pressure rotor at maximum take-off rating will decrease as the outside air temperature decreases, since the engine speed will be limited with regard to maximum fuel flow in this case.

Changes in rpm and turbine outlet gas temperature depending on atmospheric conditions are shown in Figs 40, 41, 42 and 43.

6. At subzero outside temperatures the engine must be run on fuels containing anti-icing additives.

7. Take care to prevent water from finding its way into fuel or oil.

Note: In other respects, engine operation in winter time does not differ from its operation at positive outside air temperatures.

ROUTINE MAINTENANCE

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Chapter VI

ROUTINE MAINTENANCE

Fulfilment of maintenance operations in due time and with utmost care adds much to reliability and serviceability of the engine.

Routine maintenance comprises the following kinds of maintenance:

1. Preflight maintenance. This kind of maintenance is [illegible] carried before each flight and consists in preparation of the engine for starting.

2. Engine maintenance during short-term parking of aircraft. This kind maintenance must be carried out after every flight, if the engine is not to be subjected to more complex maintenance.

Note: When an aircraft is used for training purposes, its maintenance during short - term parking is done at the time of servicing the aircraft fuel and oil, but at least once every two or three flying hours.

3. Postflight maintenance. This kind of maintenance [illegible] at base and terminal airfields every 50 ± 10 flying hours after the latest post-flight or routine maintenance.

4. Routine maintenance every 20 ± 10 engine operating hours.

5. Routine maintenance every 600 ± 50 engine operating hours.

CAUTION. Any kind of maintenance operations must be carried out with the use of tools available in the tools kit attached to the engine.

1. PREFLIGHT MAINTENANCE

To prepare the engine for a flight mission, perform operations prescribed in Section "Preparation of Engine for Starting" in Chapter III.

2. ENGINE MAINTENANCE DURING SHORT - TERM PARKING OF AIRCRAFT

1. See that there is no leakage of fuel or oil.
2. Check the amount of fuel and oil in the tanks and top up the tanks, if necessary.

3. POSTFLIGHT MAINTENANCE

1. Open the aircraft shutters and access doors.
2. Make sure there is no leakage of fuel or oil.
3. Inspect the engine oil filter МФС-30.

   Rince the filter in clean gasoline or kerosine, if necessary.

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4.Examine the chip-detecting filter of centrifugal deaerator ЦВ0-4С-30 , wash it in clean gasoline or kerosene with the use of a hair brush without stripping the signalling disc-shaped elements.Make use of a tester to check that the signalling elements are not short-circuited.Otherwise,disassemble the filter as follows:

(a) install the chip-detecting filter on appliance I9-946 so that the appliance lug enters the slot in the core;

(b) remove the textolite insulating sleeve;

(c) unbend the lock tab,undo the nut and take off the lock;

(d) remove the washer and discs of the plate-type filter,take off the core and insulating sleeve;

(e) use a piece of cloth soaked in acetone to remove coke and tar from the discs of the filter,wash all the filter component parts in c ean gasoline or kerosene;

(f) assemble the chip-detecting filter.

CAUTION. I.Each disc of the plate-type filter must be placed so that its insulating layer faces the gauze filter.

2.The nut and the plug should be tightened up to a torque of 0.I-0.3 kgm (wrench I9-9I5) and 6-I0 kgm,respectively.

3.Never install used locks and sealing rings.

4.The cotter pin head must protrude over the core by not over 4 mm.

Notes: I.If chips are detected in the filters of the lubricating oil system, consult the representative of the Manufacturing plant as to further use of the engine.

2.If fuel has been drained fromthe engine fuel control system for some reason or other,process the system within 24 hours as instructed in Chapter XII.

5.Measure the oil level in the oil tank.Add oil into the tank,if necessary. If oil level in the tank increases after flight,check oil for presence of fuel.

6.Inspect the engine air intake duct,IGVs,compressor low-pressure blades,turbine 4th stage nozzle vanes and moving blades within the vision field.Examine the exhaust unit and final jet nozzle.No damage is permissible.

7.Inspect ice detector ДО-202М,clear the impact pressure orifices of carbon deposit,if necessary,for which purpose use a piece of dence cloth.

8.Check condition of all the engine accessories and pipelines; check them for proper attachment and locking.

9.Check the plug connectors of the electrical system units for condition. Tighten them up and lock,if required.

I0.Upon inspection of the engine,close the engine air intake duct and the exhaust duct with the respective blank covers.The exhaust duct must be closed I0 or I5 minutes after stopping the engine.

Note: After first 50 ± 5 hours of engine operation inspect the fine fuel filters incorporated in fuel regulating pump HP-30 and in centrifugal governor ЦР-2В. Rinse the filters and reinstall them,having replaced their rubber sealing rings by new ones.Bleed air from fuel regulating pump HP-30 and centrifugal governor ЦР-2В.

11. Check the engine for proper running, as instructed in Section 1 of Chapter III.

4. ROUTINE MAINTENANCE EVERY 200 ± 10 ENGINE OPERATING HOURS

Perform all the operations prescribed in Section "Postflight Maintenance" of this chapter.

In addition do the following:

1. Inspect the fine fuel filters incorporated in fuel regulating pump HP-30 and in centrifugal governor HP-2B. Rinse the filters in clean gasoline or kerosene and reinstall them in position, having replaced their rubber sealing rings by new ones. Bleed air from fuel regulating pump HP-30 and centrifugal governor HP-2B.

2. Check the air pipelines running from the combustion chamber diffuser to the starting fuel control unit of fuel regulating pump HP-30 for proper connection and locking. Tighten up the union nuts and lock them, if necessary.

3. Drain oil from the lower drive gear box. If the drained oil is clean, it may be refilled into the oil tank through a silk strainer.

4. Check the starter-generators for proper attachment. Pay attention to the condition of the spring washers under the nuts on the attachment studs. Remove dust, dirt and oil stains from the starter-generators, inspect the starter-generator casings and make sure they are not damaged.

Make sure all the current-carrying cables are properly connected to the starter-generator terminals.

Check the condition of the brushes and commutators; see to it that the brushes are free fit in the brush holders; particular attention must be paid to bedding the brushes to the commutators, to the condition of the commutator surfaces and brush springs. Measure the brush length (from the longest side). Brushes whose length has been reduced to 21 mm should be changed by new ones taken from the set of spare parts. The new brushes should be properly seated to commutators (according to instructions set forth in the starter-generator certificate).

After bedding the brushes to the commutator, do not fail to blow the starter-generators with compressed air to remove carbon dust.

5. Check the inlet and outlet holes in the exhaust gas thermocouple housings for cleanliness.

Note: Oil is changed in the oil tank every 400 ± 20 hours of engine operation.

5. ROUTINE MAINTENANCE EVERY 600 ± 50 ENGINE OPERATING HOURS

1. Perform all the operations prescribed in Section "Routine Maintenance Every 200 ± 10 Engine Operating Hours".

2. Examine the oil strainers incorporated in the three pipe connections of oil scavenging pump MHO-30 coupled to the pipelines scavenging oil from the shaft tube cavity and the second turbine rear support cavity.

Inspect the magnetic plug.

ENGINE TROUBLES, THEIR CAUSES AND REMEDIES

Chapter VII

ENGINE TROUBLES, THEIR CAUSES AND REMEDIES

Nos	Trouble	Probable cause	Remedy
I	With button START depressed on the ground, the starter-generators fail to operate	No power supply to the starting system.	Check the starting system power supply circuit
		The aircraft electric system is out of order.	Check (successively) the aircraft electric system. If necessary, replace control unit
		Automatic starting control unit АПД-19ВД (series II) or panel ПСГ-2А (series II) fails to operate normally.	АПД-19ВД (series II), starter-generator control panel ПСГ-2А (series II), or centrifugal governer ЦР-2В.
		The ЦР-2В centrifugal governor microswitch or its wiring is out of order	
		Damaged contact in the plug connectors (in soldered points)	Repair the contacts by soldering or replace the plug connectors
2	Starter-generators СТГ-12ТВМО are disengaged before 45 sec elapse, when high-pressure rotor speed is below 4500 ± 200 rpm (37.0 - 40.0 %)	Faulty plug connector or microswitch of centrifugal governor ЦР-2В	Check the plug connector. Replace centrifugal governor ЦР-2В.
		Centrifugal governor ЦР-2В is out of adjustment	Manipulate the centrifugal governor adjusting screw to adjust starter-generator disengagement speed
3	The engine fails to gain idle rpm, when started in the air	Altimetric compensator of unit НР-30 is out of adjustment	Replace the starting control unit or centrifugal governor ЦР-2В

Trouble	Probable cause	Remedy
		Check the position of the engine control lever on the quadrant Manipulate the respective adjusting screw of the starting fuel control unit incorporated in fuel regulating pump HP-30 to obtain proper fuel regulation with regard to altitude
No fuel delivery during starting	An air look in the fuel system	Bleed air from the fuel system via the bleeding valves of pump HP-30 and centrifugal governor ЦP-IB
Fuel fails to the ignited in the combustion chamber	Supply voltage is insufficient. The ignition circuit wiring is damaged. The ignition plugs are out of order. Some fault in the CKHA-22-2A unit	Check the ignition unit circuit to make sure supply voltage is delivered to the CKHA-22-2A unit according to specifications Remove the ignition plugs, connect wires and check for spark formation. When performing the check, see that the ignition plug body is shorted to the ground If no spark is formed, replace the ignition plugs by new ones and repeat the spark formation check If no spark is formed, check the wires running to the ignition plugs. If the replacement of the ignition plugs and checking of the wires are of no avail, replace ignition unit CKHA-22-2A CAUTION. It is prohibited to check the operation of the ignition system with the plugs disconnected. Never strip ignition unit CKHA-22-2A
Fuel pressure drop at fuel refulating pump	The aircraft fuel system filter is clogged	Remove and inspect the aircraft fuel system

Nos	Trouble	Probable cause	Remedy
	inlet occurs during engine starting		filter; replace the filter, if necessary. Make sure fuel pump ДЦН-44-П3Т is in good condition
7	Water getting into the engine fuel system	Water may get into the system during aircraft refueling and due to improper tightness of fuel tank fillers	Drain fuel from the aircraft fuel system Replace the following automatic system equipment: fuel regulating pump НР-30, centrifugal governor ЦР-1Б, centrifugal governor ЦР-2В, and booster pump ДЦН-44-П3Т
8	Idle rpm fail to comply with the Chart in Fig.40 given in Chapter III	The fuel control system is out of order Fuel regulating pump НР-30 is out of adjustment	Check position of the lever of the throttle valve incorporated in fuel regulating pump НР-30. The lever should be between the notches limiting the idle rpm sector It is desirable that the lever is set against the middle notch.
		Tachometer generator or indicator is faulty	Check the tachometer generator and indicator Adjust idle rpm by means of the screw located on the fuel regulating pump
9	It takes more than 120 sec for the engine to gain idle rpm	Voltage in the starting power supply system is insufficient	Check the power supply sources
		The starting fuel control unit of the НР-30 pump is out of adjustment	Up to a speed of 2500 - - 3000 rpm (21.5 - 25.5%) and with turbine outlet gas temperature much below 620°C, increase fuel delivery by manipulating the screw for ground adjusting the starting fuel control unit of fuel regulating pump НР-30 With the engine slowly gaining speed in excess of 3000 rpm (25.5%) and with turbine outlet gas temperature much below 620°C,

Nos	Trouble	Probable cause	Remedy
			increase fuel delivery by replacing the air bleeding jet. Adjust the engine starting process as instructed in Section 3 of Chapter VIII
		The system supplying air at pressure P_2 to the starting fuel control unit is leaky	Use gasoline or kerosene to wash the air filter in the system for air supply to the starting fuel control unit. Blow off the filter before installing it in position. Check the air supply system for tightness
10	Excessive turbine outlet gas temperature at the beginning of engine starting, when high-pressure rotor speed is up to 2500 - 3000 rpm (21.5 - 25.5%)	Excessive fuel consumption at the first stage of starting	Reduce fuel supply by means of the screw serving for adjustment of the starting fuel control unit on the ground
11	Excessive turbine outlet gas temperature at the end of engine starting, when high-pressure rotor speed is above 2500-3000 rpm (21.5 - 25.5%)	Excessive fuel consumption as compared to rated starting characteristics	Reduce fuel supply by changing the air bleed jet in the starting fuel control unit of fuel regulating pump HP-30
12	Oil pressure at the engine inlet does not comply to the specified basic data given in Chapter I	Pump OMH-30 is out of adjustment; contraction of the spring incorporated in the pressure control valve of the pump	Adjust oil pressure at the engine inlet by means of the main oil pump pressure control valve
13	Maximum take-off rating rpm at $t_H \geqslant +15^{\circ}C$ fail to fall within the limits specified by the Service Log or at an ambient air temperature of t_H less than $+15^{\circ}C$ maximum take-off rpm are not in compliance with the Chart in Fig.42 of Chapter III	Speed measuring equipment is faulty	Check calibration of the tachometer generator and indicator
		Fuel regulating pump HP-30 is out of adjustment as regards the position of the hydraulic decelerator or wobble plate at the maximum delivery stop due to wear of parts in the HP-30 pump controls	At an ambient air temperature of t_H (see Note *) less than $+15^{\circ}C$, calculate the rpm value of the compressor h.p. section for this temperature in accordance with the respective formula with due account of the Chart in Fig.41. In case the specified rpm

*/ At an ambient air temperature of t_H equal to or more than $+15^{\circ}C$ adjust the speed by using the decelerator adjusting screw.

Nos	Trouble	Probable cause	Remedy
			value fails to agree with the rpm read off the tachometer, adjust the rpm by means of the maximum delivery screw on fuel regulating pump HP-30
		The fuel regulating pump is out of order	Replace the fuel regulating pump
14	With engine rpm gradually increasing, the air blow-off shutters aft of the 4th and 5th stages of the compressor h.p. section close and the IGVs get turned from -10° deg to zero deg at a speed other than 9400^{+125}_{-175} rpm (79.0 - 81.5%)	Centrifugal governor HP-2B is disadjusted Contraction of the spring incorporated in the slide valve of centrifugal governor HP-2B	Manipulate the adjusting screw of centrifugal governor HP-2B to adjust the rpm at which the air blow-off shutters close and the IGVs change over their position
15	With engine rpm slowly decreasing, the air blow-off shutters aft of the 4th and 5th stages of the compressor h.p. section fail to open and the IGVs fail to change over from zero to -10° deg at 9100 ± 100 rpm (77 - 79%)	Contraction of the spring incorporated in the slide valve of centrifugal governor HP-2B	Manipulate the adjusting screw of centrifugal governor HP-2Bto adjust the rpm at which the air blow-off shutters open and the IGVs change over their position
16	Engine acceleration time fails to agree with the specified data (more than 15 sec or less than 10 sec)	The flow restrictors in the hydraulic decelerator and fuel pressure rise limiter lines of the HP-30 unit are improperly installed or blocked	Remove and inspect the flow restrictors incorporated in the fuel pressure rise limiter and in the hydraulic decelerator, as well as their rubber sealing rings. Wash the flow restrictors in kerosene, if required. Adjust engine acceleration time by varying the capacity of the flow restrictors employed by the fuel pressure rise limiter and by the hydraulic decelerator of the fuel regulating pump
17	While the aircraft is climbing, the low-pressure rotor develops a speed exceeding 8000 rpm (94.0%)	Contraction of the spring incorporated in centrifugal governor HP-1B	Adjust low-pressure rotor limiting rpm with the help of the HP-1B centri-

Nos	Trouble	Probable cause	Remedy
			fugal governor adjusting screw
18	Lubricating oil leaks from the tank into the engine with the engine inoperative	The non-return valve of main oil pump OMH-30 is leaky due to faulty sealing ring or getting foreign particles under the valve	Remove the non-return valve and check it for condition Replace the sealing ring of the non-return valve
	Oil level raise in the tank	Oil gets diluted with kerosene	Check the fuel-cooled oil cooler for tightness
19	The ПРТ-35 over-temperature control system fails to limit the engine speed, or turbine outlet gas temperature at the controlled rating differs from the preset value by more than 10°C (temperature value at the rating controlled by the ПРТ-35 system must be equal to the maximum temperature limited by the ПРТ-35 system minus 110 ± 10°C)	Thermocouples T-99-1 are faulty	Check the thermocouples for proper attachment on the engine, for proper contacts and clear orifices for gas flow. Measure total resistance in the thermocouple wires running to the ИТ-2 indicator, which must be not more than 30 ohms, and of those running to the УРТ-19А-2Т amplifier, which should be within 1.5±0.2 ohms. Check to see that the thermocouple unit wires leading to the indicator and amplifier are not short-circuited Measure insulance in each thermocouple unit line; it should be not less than 20,000 ohm. The thermocouple circuits should be checked for resistance, short-circuit and insulance value with the amplifier and indicator plug connectors disjointed Calibrate the ИТ-2 indicator
		The overtemperature limiter of the НР-30 fuel regulating pump is faulty or the wires running from the limiter to the УРТ-19А-2Т amplifier are broken	Check the overtemperature limiter and its wiring for condition. Measure the resistance of the overtemperature limiter solenoid between plug connector

Nos	Trouble	Probable cause	Remedy
			pins 1 and 2, which should be within 18 and 25 ohms. The insulance between the plug connector pins and the fuel regulating pump body must be not less than 20 megohms In case the wiring and the solenoid are in proper condition, replace the НР-30 fuel regulating pump
		Power supply cables running to amplifier УРТ-19А-2Т are broken	With the power supply on and the ПРТ-35 system test switched on, measure voltage between pins 1 and 2 then between pins 1 and 3 of plug connector 2РТТ28Б7Ш11. Pin 1 is connected to the minus, pins 2 and 3 - to the plus The voltage must be equal to the on-board power supply voltage
		Amplifier УРТ-19А-2Т is faulty	Should the above stated faults be not detected, replace amplifier УРТ-19А-2Т
20	The turbine outlet gas temperature at ground take-off rating (at ambient air temperature equal to or more than +15°C) and in altitude flight is in excess of the gas temperature limit for the engine (the turbine outlet gas temperature limit equals the maximum permissible temperature value given in the Service Log plus 15°C)	The ПРТ-35 over-temperature control system is maladjusted	Manipulate the overtemperature limiter adjusting screw on fuel regulating pump НР-30, to adjust the required temperature limit and register the turbine outlet gas temperature controlled by the ПРТ-35 system in the Service Log of the УРТ-19А-2Т overtemperature amplifier
		The УРТ-19А-2Т amplifier presetter is maladjusted	Check the position of the amplifier presetter and compare its indication with the turbine outlet gas temperature limit t_{lim})

Nos	Trouble	Probable cause	Remedy
		The system for measuring turbine outlet gas temperature is faulty	Check and calibrate the indicator and thermocouples complete with their wires, as instructed in Item 19 of this chapter
21	With the engine running at a speed controlled by the ПРТ-35 system, the compressor h.p. section rotor speed does not fall within n_2 = 10,500 ± 75 rpm (89.5 - 90.5%)	The speed controlled by the ПРТ-35 system is maladjusted	Make use of screw 19 on the НР-30 fuel regulating pump to adjust the speed controlled by the ПРТ-35 overtemperature control system, as instructed in Section 6 of Chapter VIII
		The controlled speed is reduced due to wear of parts incorporated in the centrifugal transmitter control system	
22	With the test button incorporated in engine fire alarm system 2С7К depressed, the indicating light fails to come on	Fire detector thermoelement is broken	Replace the fire detector The electrical resistance between the plug connector pins of a sound fire detector should be within 1 ± 0.2 ohm
		Broken wires running from fire detector to control unit, from control unit to indicating light or from control unit to test button	Connect broken wires
		Burnout of the indicating light	Replace the indicating light
23	The indicating light of fire alarm system 2С7К is on with the test button disengaged	Closure of the contact of relay РПС-5	Replace control unit 2С7К with a sound one
24	Pressure warning unit СДУ2-0,15 incorporated in the deicing system does not operate	The total and static pressure chambers of the pressure switch are not tight	Check the total pressure chamber for tightness at a pressure of 4.8 kg/sq.cm; leaks are not permissible; The checkup must be carried out for one minute Check the static pressure chamber for tightness at a pressure of 300 mm Hg; the

Nos	Trouble	Probable cause	Remedy
			pressure drop should not exceed 8 mm Hg per one minute Replace the pressure switch if it is leaky
25	Turbine outlet gas temperature at any operating rating of the engine exceeds the specified limits	A trouble in the turbine outlet gas temperature measurement system	Check and calibrate the indicator complete with the thermocouples and wires, as set forth under Item 19 of this chapter
		The butterfly valves in the air bleed lines aft of the 5th and 10th stages of the compressor h.p. section fail to operate	Replace the butterfly valve units
		The air bleed valve aft of the 10th stage of the compressor h.p. section is leaky	Remove the valve cover and check to see that there is no foreign particles between the valve and its seat
		The air bleed pipelines running to the aircraft or engine air systems are not tight	Repair leaky connections
		The air blow-off shutters aft of the 4th and 5th stages of the compressor h.p. section fail to operate	Check the air blow-off shutters and their actuating cylinders for condition
26	Severe sparking at the brushes and the commutator of starter-generator СТГ-12ТМО	The brushes do not seat properlly to the commutator surface due to sticking of the brushes in the brush holders	Withdraw the brushes from the brush holders, dress them slightly with the use of fine glass paper No.180 - 220 grit
		The brushes are badly bedded	Dress up and bed the brushes
		The commutator is dirty	Clean the commutator with a piece of clean cloth slightly wetted in gasoline. Make use of fine glass paper No. 180 - 220 grit, if necessary, rotating the armature by hand
		The commutator bars are loose or the commutator has worked oval	Dismount the starter-generator to have it repaired

Nos	Trouble	Probable cause	Remedy
		The commutator bars are heavily worn out	Dismount the starter-generator to have it repaired
		The armature winding is short-circuited	Clean the gaps between the commutator bars. In case the trouble persists, forward the starter-generator for repair and replacement of its armature
		The armature winding is broken	Remove the starter-generator to have it repaired
27	No voltage at the starter-generator output terminals	The brushes do not contact the commutator	Dress up the brushes as set forth in Item 26 above
		The excitation winding is broken	Remove the starter-generator and forward it for repair
		The armature winding is short-circuited	Remove the starter-generator to have it repaired
		The armature winding is short-circuited owing to accumulation of brush dust between current-carrying parts of the starter-generator	Eliminate the trouble by blowing out the starter-generator with compressed air. If the trouble is not eliminated in this way, remove the starter-generator to forward it for repair
		The starter-generator is demagnetized	Magnetize the starter-generator by connecting a storage battery to the excitation winding ends for one or two seconds (terminal "+" of the storage battery should be connected to terminal "Ш", terminal "-" to the minus of the winding)
		The starter-generator flexible shaft is damaged	Remove the starter-generator to forward it for repair
		The slipping clutch of the starter-generator is faulty	Replace the drive slipping clutch

Nos	Trouble	Probable cause	Remedy
26	The engine fails to accelerate to idle speed during starting; fuel pressure stops rising when the engine is petering out; the turbine outlet gas temperature does not rise	The current parameters across the starter-generator terminals do not correspond to the specified values	Ensure the specified current parameters across the starter-generator terminals
		The throttle valve control lever of fuel regulating pump HP-30 is not set at the idle sector	Adjust the position of the throttle valve control lever relative to the middle notch on the idle sector
		The air valve or air pipeline supplying compressed air to the starting fuel control unit of fuel regulating pump HP-30 is not tight enough	Check the air valve and the pipeline supplying compressed air to the starting fuel control unit. Replace the air valve or tighten up the pipeline connections, if required

25X1

ADJUSTMENT OF ENGINE ACCESSORY UNITS

25X1

Chapter VIII

ADJUSTMENT OF ENGINE ACCESSORY UNITS

CAUTION. Prior to adjusting engine accessory unit, make sure the respective measuring instruments are properly calibrated.

In the event some of the engine parameters fail to agree with the specified values during engine trying out or in service, the following adjustments are allowed to be carried out:

1. Oil pressure at the engine inlet;
2. Fuel pressure at the inlet to fuel regulating pump HP-30;
3. Acceleration characteristics of the starting fuel control unit incorporated in fuel regulating pump HP-30;
4. Idling speed;
5. Maximum take-off rating rpm of the compressor high-pressure rotor;
6. Engine speed limited by overtemperature control system ПРТ-35;
7. Maximum permissible turbine outlet gas temperature;
8. Acceleration;
9. Starter-generator disengagement speed;
10. Speed at which air blow-off shutters aft of the 4th and 5th stages of the compressor high-pressure section close and the compressor high-pressure section IGVs turn with the engine speed increasing;
11. Speed at which the air blow-off shutters open and the IGVs change over their position with the engine speed decreasing;
12. Compressor low-pressure rotor rpm limit.

<u>Notes:</u> 1. Adjustments referred to in Items 2, 5, 6, 7, 8 and 12 are to be carried out by the representative of the engine Manufacturing plant.
2. Make a record of all the adjustments made on the engine accessories in the engine Service Log and in the certificates of the accessories.

The adjustment procedures are described below.

1. ADJUSTING OIL PRESSURE AT ENGINE INLET

Engine inlet oil pressure (downstream of oil filter MФC-30) is accomplished with the aid of the pressure control valve incorporated in main oil pump MH-30 (Fig.45), using the following procedure:

1. Unlock and unscrew locking nut 2.
2. Turn adjusting screw 1 through the required number of revolutions in the proper direction.

Turning of the screw in the clockwise direction will cause oil pressure to increase, and vice versa. One complete turn of the screw will change oil pressure by 0.5 kg/sq.cm. Oil pressure must be adjusted at 0.7 normal rating to a value of 4 ± 0.2 kg/sq.cm.

[redacted]

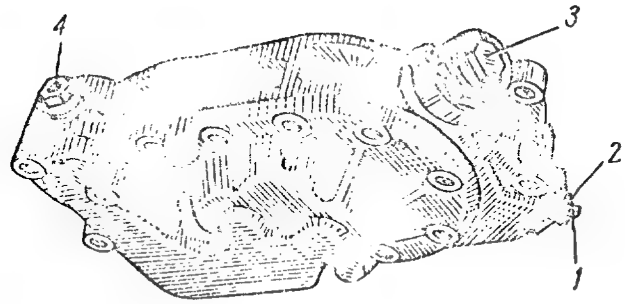

FIG. 45. MAIN OIL PUMP OMH-30
1 – pressure control valve adjusting screw, 2 – palnut; 3 – non-return valve; 4 – air bleed plug.

3. Tighten up and lock locking nut 2.

2. ADJUSTING FUEL PRESSURE AT INLET TO FUEL REGULATING PUMP HP-30

Fuel pressure at the inlet to fuel regulating pump HP-30 is carried out with the use of the throttling valve adjusting screw incorporated in fuel booster pump ДЦН-44-ПЗТ (Fig.46), using the following procedure:

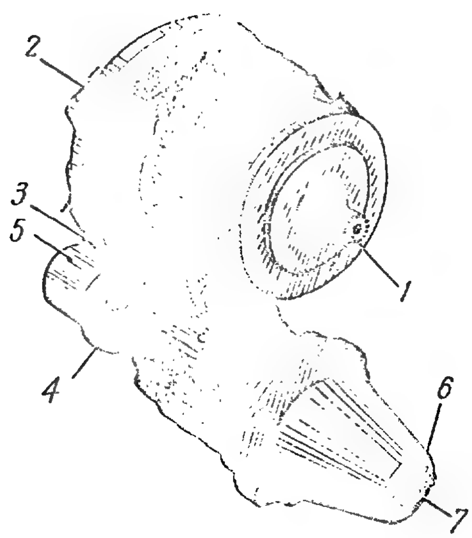

FIG. 46. FUEL BOOSTER PUMP ДЦН-44-ПЗТ
1 – pump drive shaft, 2 – inlet pipe connection attachment flange; 3 – fuel drain cock, 4 – drain pipe union; 5 – fuel outlet pipe connection; 6 – locking washer, 7 – fuel throttling valve adjusting screw.

1. Unlock and turn the locking washer screw.
2. Remove locking washer 6 used for securing adjusting screw 7.
3. Turn adjusting screw 7 of the throttling valve in the proper direction.

[redacted]

Turning of the adjusting screw in the clockwise direction will cause increase in fuel pressure, and vice versa. One complete turn of the screw will change fuel pressure downstream of pump ДЦН-44-ПЗТ by 0.2 kg/sq.cm.

4. Reinstall the locking washer, drive the screw in and lock it properly.

3. ADJUSTING ACCELERATION CHARACTERISTICS OF STARTING FUEL CONTROL UNIT INCORPORATED IN FUEL REGULATING PUMP HP-30

Adjustment of the starting characteristics is done with the aid of starting fuel control unit screw 21 or jet 27 serving for bleeding air from the membrane space of the starting fuel control unit incorporated in fuel regulating pump HP-30 (Fig.48). Screw 21 is used for carrying out adjustment within the compressor high-pressure rotor speed range of up to 3000 rpm (25.5%).

If during engine starting an increase in the speed of the compressor high-pressure rotor involves an abrupt rise in exhaust gas temperature, reduce the amount of fuel supplied into the engine by turning starting fuel control unit screw 21 in the counter-clockwise direction. In case the compressor high-pressure rotor fails to pick up speed during engine acceleration and no rise in turbine outlet gas temperature is experienced, increase the amount of fuel fed into the engine by turning starting fuel control unit screw 21 in the clockwise direction.

Within the speed range of from 3000 rpm (25.5%) to idling speed adjustment is accomplished by replacing jet 27 serving for air bleed from the membrane space of the starting fuel control unit.

An increase in the jet diameter will result in more slow engine acceleration and will reduce exhaust gas temperature rise. The jet diameter varies from 2.0 to 2.3 mm.

<u>Notes</u>: 1. The starting fuel control unit adjusting screw must be turned through 0.5 of a turn at a time with subsequent engine starting for checking the result.
2. The diameter of the bleeding jet should not be changed by more than 0.1 at a time with subsequent engine starting for checking purposes.

It should be borne in mind that the initial pressure surge in the primary fuel manifold must be within 13 - 15 kg/sq.cm, as measured with the use of a pressure gauge of the 0.6 accuracy class.

Engine starting characteristics at a high altitude are adjusted by means of screw 30 serving for altitude adjustment of the starting fuel control unit (Fig.48). With the screw turned in the clockwise direction, the starting fuel control unit will start regulating fuel supply at a lower altitude, with the screw turned counter-clockwise, the starting fuel control unit will start regulating fuel supply at a higher altitude.

Adjusting screw 30 may not be turned more than by 1 turn clockwise and by 2 turns counter-clockwise relative to the position adjusted at the Manufacturing plant.

4. ADJUSTING IDLING SPEED

Engine idling speed is adjusted by means of adjusting screw 15 incorporated in fuel regulating pump HP-30 (Fig.47). When turned through one complete turn, the

screw changes idling speed by 700 rpm (6%). Turning of the screw head in the clockwise direction will cause engine rpm to decrease, and vice versa.

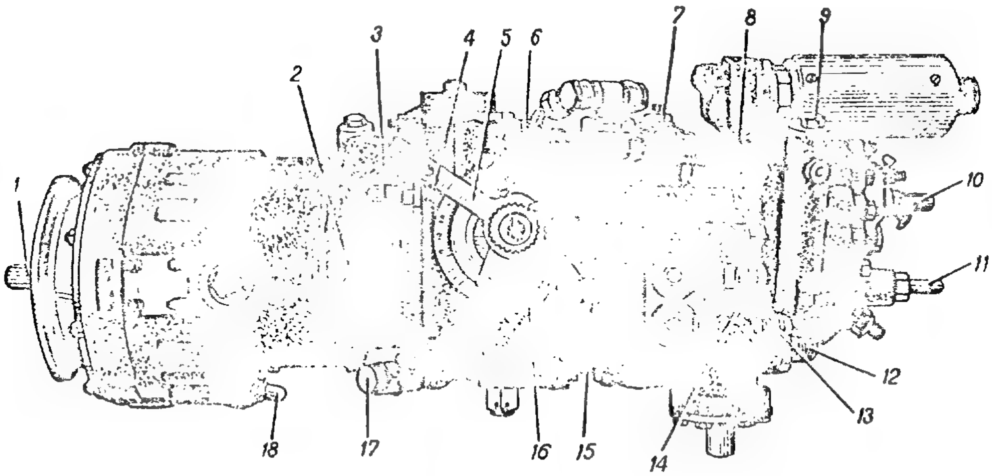

FIG. 47. FUEL REGULATING PUMP HP-30
(control lever side view)

1 – fuel regulating pump drive shaft; 2 – union for delivery of high-pressure fuel to centrifugal speed governor ЦР-2И, 3 – screw for adjusting beginning of automatic operation; 4 – central fuel filter; 5 – throttle valve control lever; 6 – TAKE-OFF stop; 7 – union for conveying fuel from hydraulic decelerator to centrifugal speed governor ЦР-1И; 8 – hydraulic decelerator flow restrictor (return travel line), 9 – hydraulic decelerator flow restrictor (direct travel line), 10 – take-off speed adjusting screw; 11 – overtemperature limiter adjusting screw; 12 – union for dumping fuel from fuel manifolds into drain tank; 13 – union supplying fuel to main (large-slot) manifold; 14 – union supplying fuel to primary (small-slot) manifold, 15 – idling speed adjusting screw; 16 – CUT-OFF stop; 17 – fuel regulating pump air bleed valve; 18 – maximum fuel flow limit adjusting screw.

Adjustment of idling speed should be carried out on a warmed-up engine, with the throttle valve control lever position indicator set against the middle notch of the idle sector on the HP-30 fuel regulating pump dial.

To determine proper idling speed with regard to the ambient air temperature and pressure, refer to the Chart in Fig.40.

5. ADJUSTING MAXIMUM TAKE-OFF SPEED OF COMPRESSOR HIGH-PRESSURE ROTOR

Whenever engine maximum take-off rpm fail to agree with the rpm values specified in Fig.41 at the given atmospheric conditions, or after replacing the fuel regulating pump in the course of service, engine maximum take-off speed is to be readjusted as follows:

(a) If outside air temperature on the ground exceeds the maximum temperature of the limiting zone with regard to the wobble plate tilt angle (above +15°C at an atmospheric pressure of 750 mm Hg refer to Fig.41), adjustment of the maximum take-off speed of the compressor high-pressure rotor must be carried out with the aid of screw 10 of the hydraulic decelerator incorporated in fuel regulating pump HP-30 (Fig.47).

Turning screw 10 in will reduce maximum take-off rating rpm, and turning it out will increase maximum take-off rating rpm. One complete turn of the screw changes maximum take-off rating speed by 200 rpm (about 1.5%). Engine speed must be adjusted to rpm value specified in the engine Service Log for maximum take-off rating with an allowance of within ± 15 rpm.

Whenever engine rpm is adjusted by means of the hydraulic decelerator screw, do not fail to turn in the respective direction screw 6 of the TAKE-OFF stop on fuel regulating pump HP-30 twice as much as the hydraulic decelerator screw.

When the outside air temperature on the ground is above the maximum temperature of the limiting zone with regard to the wobble plate angular position, checking of maximum take-off speed is carried out on the ground; if the outside air temperature on the ground is below the maximum temperature of the limiting zone with regard to the wobble plate position, check-up of maximum take off speed must be carried at an altitude of 3 or 4 km at a maximum flight speed corresponding to that altitude.

If the outside air temperature at an altitude of 3 or 4 km is below standard more than by 20°C, compressor high-pressure rotor maximum take-off speed cannot be checked because compressor low-pressure speed is limited by centrifugal governor ЦР-1В.

In this case the adjusted speed of the compressor high-pressure rotor with the hydraulic decelerator of fuel regulating pump HP-30 at the stop is to be checked at the above altitude at a higher temperature of ambient air.

When checking the adjusted maximum take-off speed in flight, record rpm of the compressor low- and high-pressure rotors, turbine outlet gas temperature and ambient air temperature.

Notes:
1. Before adjusting maximum take-off speed do not fail to check the travel of the throttle valve control lever relative to the dial of fuel regulating pump HP-30. With the engine control lever in the pilot's cabin set at the TAKE-OFF stop, the throttle valve lever of fuel regulating pump HP-30 must be also at the TAKE-OFF stop.
2. When checking maximum take-off speed, do not allow compressor high-pressure rotor rpm to rise in excess of 11,650 rpm (100%) and turbine outlet gas temperature to exceed the value limited by the ПРТ-35 over-temperature control system.
3. Maximum take-off speed should be checked with the ПРТ-35 overtemperature control system cut off.

(b) When outside air temperature is below the maximum temperature of the limiting zone with regard to the wobble plate position, compressor high-pressure rotor maximum take-off speed on the ground is limited by the maximum output of fuel regulating pump HP-30 and is adjusted by means of wobble plate stop screw 18 (Fig.47).

One complete turn of wobble plate stop screw 18 will change compressor high-pressure rotor speed by 220 - 250 rpm (about 2%) and fuel output by 360 kg/hr.

Rotation of the screw in the counter-clockwise direction will cause an increase in rpm, and vice versa. Adjustment is checked on the ground.

The rpm values obtained on the engine must correspond to the data presented in Fig.41, which is checked by the use of the following formula:

$$n_{2\,meas} = \left(n_{2\,spec} - \Delta n_2\right)^{+100\ (+1\%)}_{-150\ (-1.5\%)}\ [rpm],$$

where: $n_{2\,meas}$ is compressor high-pressure rotor rpm measured by the aircraft instrument in flight at maximum take-off rating;

$n_{2\,spec}$ is maximum take-off rating rpm specified in the engine Service Log;

Δn_2 is correction of maximum take-off rating rpm at given atmospheric conditions, as presented in Fig.41.

No adjustment of engine rpm is required, if $n_{2\,meas}$ differs from $(n_{2\,spec} - \Delta n_2)$

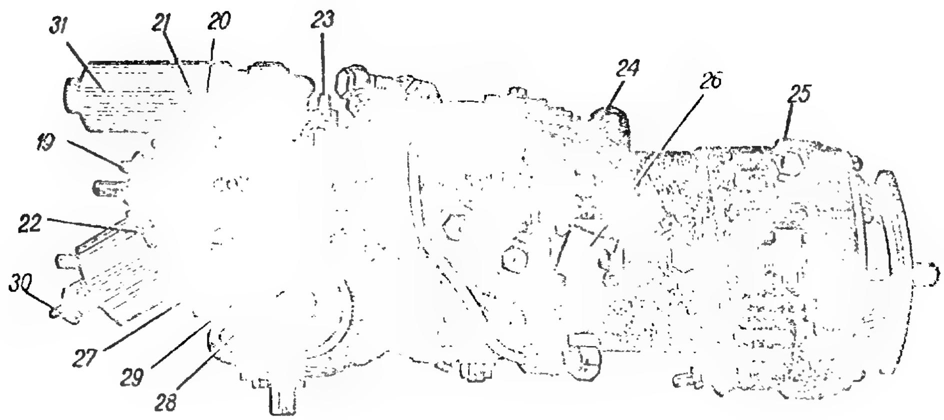

FIG. 49. FUEL REGULATING PUMP HP-30
(fuel inlet connection side view)

19 – overtemperature control limiting speed adjusting screw; 20 – temperature limiter flow restrictor, 21 – starting fuel control unit ground adjusting screw; 22 – pipe union supplying air pressure P_2 to starting fuel control unit, 23 – screw for adjustment of fuel flow divider; 24 – isodrome flow restrictor; 25 – fuel regulating pump drain connection; 26 – flange for installation of fuel inlet connection; 27 – jet for correction of pressure P_2 supplied to starting fuel control unit, 28 – fuel pressure rise limiter flow restrictor No. 1; 29 – fuel pressure rise limiter flow restrictor No. 2; 30 – starting fuel control unit altitude adjusting screw, 31 – overtemperature control proportional solenoid

by not more than by plus 100 or minus 150 rpm and is not above the rpm value taken from the engine Service Log.

6. ADJUSTING ENGINE SPEED LIMITED BY OVERTEMPERATURE CONTROL SYSTEM ПРТ-35

Adjustment of engine speed limited by the ПРТ-35 overtemperature control system at 100 per cent cycle duration ratio is accomplished with the aid of a slide valve incorporated in fuel regulating pump НР-30.

Engine speed limited by fuel flow should be within n_2 = 10,500 ± 75 rpm (89.5 - 90.5%). The speed is adjusted by means of screw 19 incorporated in fuel regulating pump НР-30. Turning the screw clockwise will increase the speed at which fuel flow is limited by the ПРТ-35 system, and vice versa.

One complete turn of the screw changes the fuel flow limit speed approximately by 200 rpm (about 1.5%).

Fuel flow limit speed is to be checked in the following cases:

- after adjusting maximum take-off speed with regard to the hydraulic decelerator;
- after replacement of fuel regulating pump НР-30;
- after replacing the engine.

Fuel flow limit speed should be checked on a warmed-up engine, using the following procedure:

1. Bring the engine to maximum take-off rating speed and run it for 10 or 15 sec at that speed.
2. Set the ПРТ-35 system selector switch in position FUEL FLOW LIMIT SPEED (ОГРАНИЧЕНИЕ ОБОРОТОВ СРЕЗКИ) and operate the engine for 20 to 30 sec. As a result, compressor high-pressure rotor speed must drop to n_2 = 10,500 ± 75 rpm (89.5 - 90.5%)
3. Upon checking the fuel flow limit speed, reduce engine rpm to idle and return the ПРТ-35 system selector switch to the operation position.

<u>Note</u>: If need arises to adjust maximum take-off rating rpm and fuel flow limit speed, carry out the adjustment of maximum take-off rating rpm first.

7. ADJUSTING TURBINE OUTLET GAS TEMPERATURE LIMITED BY OVERTEMPERATURE CONTROL SYSTEM ПРТ-35

Overtemperature controller ПРТ-35 is adjusted to a temperature limit equal to the turbine outlet gas temperature at engine maximum take-off rating taken from the engine Service Log and increased by 15°C. The overtemperature controller is adjusted to this temperature by means of presetter adjusting knob 6 on overtemperature amplifier УРТ-19А-2Т (Fig.49) and by the use of overtemperature limiter adjusting screw 11 (Fig.47) incorporated in fuel regulating pump НР-30. The adjusting procedure is as follows:

1. Undo the screws fastening adjusting knob cover 1 on amplifier УРТ-19А-2Т. Hinge off the cover and turn presetter knob 6 to set it against the division corresponding to the desired temperature limited by the ПРТ-35 system.

The amplifier presetter makes it possible to vary the temperature limit within 570 - 670°C. The presetter dial is graduated through every 10°C and has several numbered divisions.

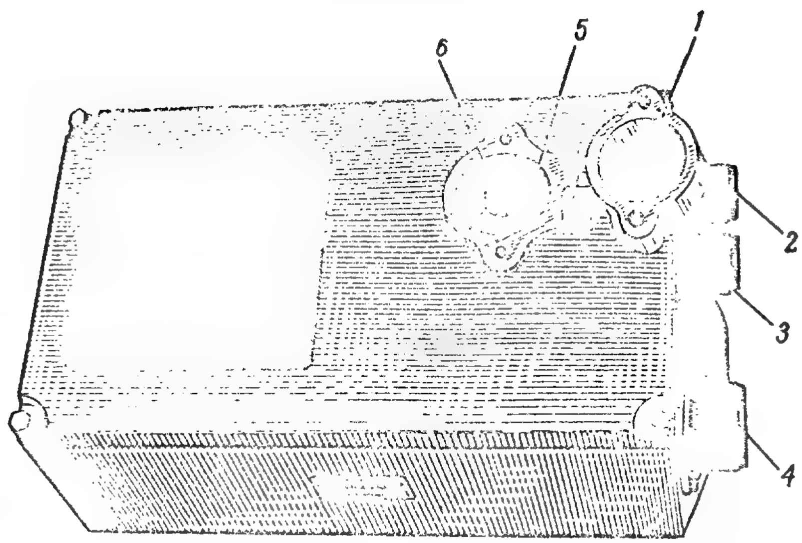

FIG. 49. AMPLIFIER УРТ-19А-2Т

1 – adjusting knob cover; 2 – plug connector for jointing T-99-1 thermocouple unit, 3 – plug connector for jointing TEST power supply; 4 – plug connector for jointing temperature limiter and overtemperature controller ИРТ-35, 5 – dial scale graduated in centigrade degrees; 6 – adjusting knob.

2. Check to see that the position of the thermocouple calibration group selector of indicator HT-2 and of the knob of amplifier УРТ-19А-2Т corresponds to the calibration group of thermocouples T-99-1 installed on the engine; if otherwise, change over the position of the indicator and amplifier selectors in accordance with the calibration group of thermocouples T-99-1, as advised in Section "Replacement of Overtemperature Amplifier УРТ-19А-2Т" of Chapter IX.

Upon completion of adjustment, reinstall the cover on the upper panel and secure it by driving in the screws.

3. Start the engine. When running the engine at idle, cut in the tumbler switch effecting the ИРТ-35 overtemperature control system test.

Accelerate the engine to bring it to the rating controlled by the ИРТ-35 system. The throttle valve lever of the HP-30 fuel regulating pump must be at the TAKE-OFF stop at that time. Turbine outlet gas temperature controlled by the ИРТ-35 system must be equal to maximum permissible temperature minus 110_{-5}°C.

4. If turbine outlet gas temperature controlled by the ИРТ-35 system is below the specified value, it is mandatory to turn in overtemperature limiter adjusting screw 11 (Fig.47) incorporated in fuel regulating pump HP-30. Turn the screw out, if the controlled temperature is above the specified value.

The overtemperature limiter adjusting screw may not be rotated by more than 8 turns in either direction relative to the position set during adjustment at the Manufacturing plant.

One complete turn of the overtemperature limiter adjusting screw will change turbine outlet gas temperature controlled by the ИРТ-35 system approximately by 3.5°C.

Note: The operations prescribed under Items 3 and 4 of this section must be carried out with the air bleed system to the aircraft needs disconnected. Prior to adjusting amplifier УРТ-19А-2Т and the overtemperature limiter of fuel regulating pump НР-30, measure total resistance of the thermocouple unit complete with its wiring running to the ИТ-2 indicator and УРТ-19А-2Т amplifier, as instructed in Item 19 of Chapter VII. Calibrate indicator ИТ-2 of the turbine outlet gas temperature measuring system. The ПРТ-35 overtemperature control system should be calibrated with due account for the indicator error correction.

5. The overtemperature controller is checked in service for proper adjustment by cutting in the tumbler switch designed for testing the ПРТ-35 system, as it is set forth in Section "Engine Warming-Up and Trial" of Chapter III; turbine outlet gas temperature control by the ПРТ-35 system must take place at a temperature 110 ± 10°C below the temperature limit adjusted by the presetter of amplifier УРТ-19А-2Т.

8. ADJUSTING ENGINE ACCELERATION

Adjustment of engine acceleration is done by changing flow restrictors No.1 and No.2 incorporated in the fuel pressure rise limiter and in the hydraulic decelerator direct control lines respectively (see Figs 47 and 48).

Flow restrictors of higher capacity will reduce time required for engine acceleration, and vice versa.

Acceleration characteristics are checked as follows:

1. Check engine acceleration time from the speed corresponding to the beginning of automatic operation, i.e. n_2 = 9700 ± 50 rpm (82.5 - 83.5%) up to a speed by 180 rpm (1.5%) less than the indicated rpm at maximum take-off rating.

The engine acceleration time must be within 7 - 14 sec. The rate of speed increase from the beginning of automatic operation to the speed by 180 rpm less than the maximum measured take-off rating speed is determined by flow capacity of hydraulic decelerator flow restrictor 9. Adjust engine acceleration time by selecting the flow restrictor of a proper capacity, if necessary.

2. Check engine acceleration time from idle to a speed by 180 rpm (1.5%) less than measured maximum take-off rating rpm. The engine acceleration time should fall within 10 - 15 sec. The rate of speed increase from idle rpm to a speed of 8500 rpm (73%) is determined by the capacity of flow restrictor No.1 (flow restrictor 28) incorporated in the fuel pressure rise limiter; the rate of speed increase from 8500 rpm to the speed which is by 180 rpm less than maximum measured take-off rating rpm is determined by the capacity of flow restrictor No.2 (flow restrictor 29) incorporated in the fuel pressure rise limiter.

If need arises, adjust engine acceleration time by selecting the fuel pressure rise limiter flow restrictors.

The flow capacities of the flow restrictors incorporated in fuel regulating pump НР-30 must be as follows:

- hydraulic decelerator flow restrictor installed in direct travel line 50 - 75 cu.cm/min,
- hydraulic decelerator flow restrictor in reverse travel line 40 - 100 cu.cm/min,
- flow restrictor No.1 incorporated in the fuel pressure rise limiter 50 - 90 cu.cm/min,
- flow restrictor No.2 incorporated in the fuel pressure rise limiter 100 - 195 cu.cm/min,

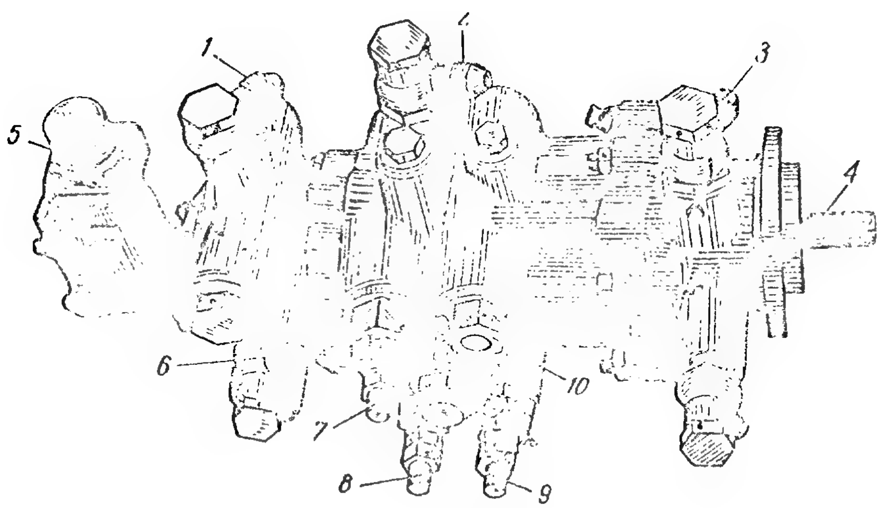

FIG. 50. CENTRIFUGAL SPEED GOVERNOR HP-2B

1 – union for high-pressure fuel delivery to air blow-off valve and butterfly valve actuators; 2 – union for supply of high-pressure fuel from fuel regulating pump HP-30; 3 – union for fuel drain line to centrifugal speed governor HP-1B; 4 – governor shaft; 5 – plug connector; 6 – union supplying fuel to IGV actuator; 7 – screw adjusting speed at which IGVs turn from –10° to 0° angular position, air blow-off shutters get closed and air bleed butterfly valves change over their position with compressor high-pressure rotor speed increasing; 8 – screw adjusting speed at which IGV position angle is changed over from 0 to –10°, air blow-off shutters get open and air bleed butterfly valves change over their position with compressor high-pressure rotor speed decreasing; 9 – СТГ-12ТМО starter-generator cut out speed adjusting screw; 10 – fine fuel filter.

- overtemperature limiter flow restrictor 170 - 190 cu.cm/min } for reference
- isodrome line flow restrictor 130 - 140 cu.cm/min.

9. ADJUSTING GTP-12TBMO STARTER-GENERATOR DISENGAGING SPEED

Starter-generator disengaging speed is adjusted by means of screw 9 (Fig.50) located in centrifugal speed governor ЦР-2В.

When screw 9 is rotated in the clockwise direction, starter-generator disengaging speed will increase, and vice versa. One complete turn of screw 9 will change starter-generator disengaging speed by 200 rpm (about 1.5%).

Starter-generator disengaging speed must be adjusted to 4500 ± 100 rpm (37.5 - 39.5%). In service the starter-generator disengaging speed may fall within the range of 4500 ± 200 rpm (37.0 - 40.0%).

10. ADJUSTING SPEED AT WHICH AIR BLOW-OFF SHUTTERS CLOSE AND COMPRESSOR HIGH-PRESSURE SECTION IGVs CHANGE OVER THEIR POSITION WITH ENGINE SPEED INCREASING

Adjustment of air blow-off shutter closing speed is performed by manipulating screw 7 arranged on centrifugal governor ЦР-2В (Fig.50).

Turning screw 7 in the clockwise direction increases air blow-off shutter closing speed, turning it counter-clockwise will reduce air blow-off shutter closing speed accordingly. One complete turn of screw 7 changes shutter closing speed by 350 rpm (3%). Air blow-off shutter closing speed must be adjusted to 9400 ± 50 rpm (80.0 - 81.0%). In service air blow-off shutter closing speed may vary within 9400^{+125}_{-175} rpm (79.0 - 81.5%).

Closing the air blow-off shutters takes place simultaneously with changing over the position of the butterfly valves bleeding air for heating the compressor low-pressure section inlet guide vanes, inlet nose bullet and air intake (air bleed is changed over from the 10th to the 5th stage of the compressor high-pressure section) and with changing over the position of the compressor high-pressure section IGVs from - 10 deg to zero. When the IGVs are turned from -10 deg to zero degree position, the respective indicating light goes out.

When the air blow-off shutters aft of the 4th and 5th stages of the compressor high-pressure section occurs, a fuel pressure rise takes place at the inlet to fuel regulating pump НР-30.

11. ADJUSTING SPEED AT WHICH AIR BLOW-OFF SHUTTERS OPEN AND COMPRESSOR HIGH-PRESSURE SECTION IGVs CHANGE OVER THEIR POSITION WITH ENGINE SPEED DECREASING

Adjustment of speed at which the air blow-off shutters open and the compressor high-pressure section IGVs change over their position from zero to -10 deg is carried out with the aid of screw 8 incorporated in centrifugas speed governor ЦР-2В (see Fig.50), with the engine speed decreasing to n_2 = 9100 ± 50 rpm (77.5 - 78.5%). In the course of service run this speed should fall within the range of n_2 = 9100 ± 100 rpm (77.0 - 79.0%).

Turning the screw in the clockwise direction will increase the speed at which the air blow-off shutters open and the IGVs change over their position, and vice versa.

25X1

One complete turn of the screw changes the speed under consideration approximately by 350 rpm (about 3.0%).

With the engine control lever swiftly retarded, the air blow-off shutters may open at a lower speed but not less than 8700rpm (74.5%) and the IGVs may change over their position at a still lower speed but not less than 7600 rpm (65%). When decelerating the engine, air blow-off shutter opening speed and speed at which the IGVs change over their position are checked respectively by reference to the pressure gauge, indicating fuel pressure in the primary fuel manifold, and to the IGV position indicating light that must come on. Opening of the air-blow off shutters involves an instantaneous fuel pressure decrease upstream of the fuel burners.

As the engine speed reduces, opening of the air blow-off shutters aft of the 4th and 5th stages and changing over of the position of the compressor high-pressure section IGVs take place simultaneously with switching over of the butterfly valves which close the air bleed line from the 5th stage and open the air bleed from the 10th stage of the compressor high-pressure section to supply compressed air for heating the compressor low-pressure section IGVs, nose bullet and aircraft air intake duct.

12. ADJUSTING COMPRESSOR LOW-PRESSURE ROTOR RPM LIMIT

Compressor low-pressure rotor rpm limit is adjusted by means of adjusting screw 4 of centrifugal speed governor ЦР-1Б (Fig.51).

Turning screw 4 in the governor body will cause compressor low-pressure rotor limit speed to increase, turning it out of the body brings about a reduction in compressor low-pressure rotor limit speed. One complete turn of the screw changes compressor low-pressure rotor limit speed by 360 rpm (about 4.22%).

Compressor low-pressure rotor limit speed is adjusted by means of centrifugal governor ЦР-1Б under the conditions of the Manufacturing plant and it is not to be adjusted in service. Replacement of centrifugal governor ЦР-1Б calls for readjustment of compressor low-pressure rotor rpm limit, which must be approved by the representative of the engine Manufacturing plant.

Compressor low-pressure rotor rpm limit is adjusted in accordance with the following procedure:

(a) Install special measuring appliance $A\frac{6012}{0270}$ on the screw intended for adjustment of compressor low-pressure rotor rpm limit and set the screw protrusion (h_1) corresponding to n_1 = 7500 rpm (88%) and taken from the centrifugal governor certificate;

(b) measure compressor low-pressure rotor speed $n_{1\,meas}$ that may differ from the speed value (n_1 = 7500 rpm) recorded in the certificate of centrifugal governor ЦР-1Б;

(c) proceeding from the difference between the compressor low-pressure rotor rpm limit $n_{1\,lim}$ = 7950 rpm and rpm value measured in compliance with Item (b), determine required protrusion of the screw (h) to limit the compressor low-pressure rotor speed.

The screw protrusion is set by means of appliance $A\frac{6012}{0270}$, having determined h from the formula:

$$h = h_1 - \frac{(7950 - n_{1\,meas})\ 0.483}{\Delta h_{spec}} \quad [mm],$$

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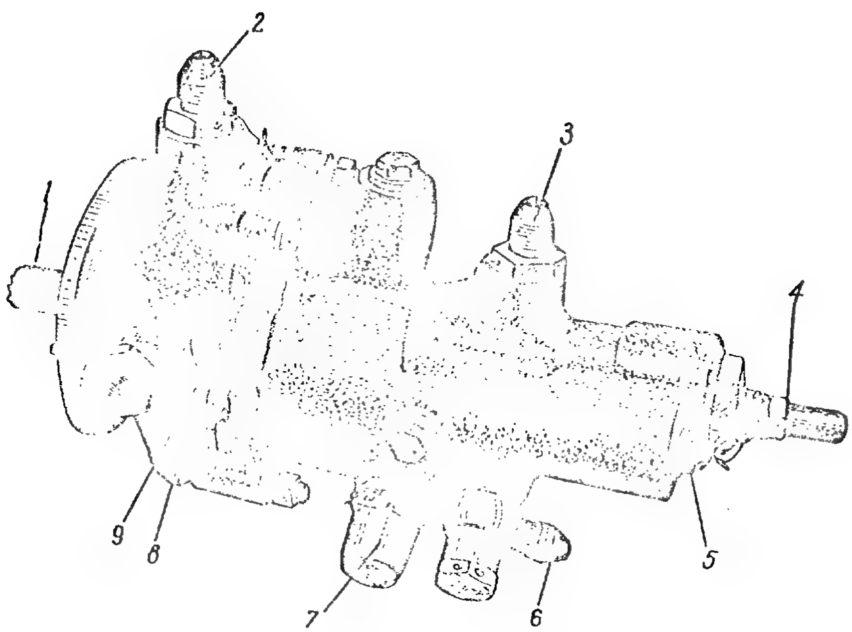

FIG. 51. CENTRIFUGAL SPEED GOVERNOR HP-1B

1 – governor shaft; 2 – union for draining fuel into drain tank, 3 – union for draining fuel from centrifugal speed governor HP-2B; 4 – screw for adjusting speed limit of compressor low-pressure rotor; 5 – flow restrictor; 6 – union for fuel supply from hydraulic decelerator of fuel regulating pump HP-30; 7 – air bleed valve; 8 – union for measuring fuel pressure at fuel regulating pump inlet; 9 – union for draining fuel into fuel regulating pump HP-30.

where: h_{spec} is the adjusting screw division value recorded in the centrifugal governor certificate.

The adjusting screw pitch equals 0.5 mm.

(d) make a note of the adjusting screw protrusion and respective compressor low-pressure rotor rpm limit in the certificate of centrifugal governor ЦР-1В. The limit speed should fall within 7950^{+50}_{-25} rpm (93.0 - 94.0%).

When running the engine at a speed equal to the compressor low-pressure rotor rpm limit, compressor high-pressure speed is allowed to fluctuate within ± 30 rpm (±0.25%) on the ground and within ± 50 rpm (±0.5%) at an altitude of 10 km. In case the speed fluctuation is beyond the permissible limits, install a flow restrictor of lower flow capacity in centrifugal governor ЦР-1В.

The flow capacity of the restrictor incorporated in centrifugal governor ЦР-1В should be within 110 - 120 cu.cm/min.

Adjustment of compressor low-pressure rotor rpm limit may be checked in flight at an altitude of from 6600 - 8000 m and minimum permissible flight speed (M = 0.55), having brought the respective engine to maximum take-off rating.

REPLACEMENT OF ENGINE UNITS AND ASSEMBLIES

Chapter IX

REPLACEMENT OF ENGINE UNITS AND ASSEMBLIES

GENERAL

If any defects develop in the engine units and assemblies during operation, which cannot be corrected in field, perform replacement of the units and assemblies in question, adhering to the following recommendations.

1. Make use of the specified tools contained in the tools kit for assembling purposes. Never use extension levers or improper tools.

2. Before dismantling fuel and oil system units, drain fuel and oil respectively.

3. When removing units and assemblies, it is allowed to knock on the stiffeners with a mallet or a wooden drift. Do not use a screwdriver or another sharp metal object.

4. Plug the holes resulting from dismantling of the pipelines, units and assemblies.

5. Treat units and assemblies dismantled from the engine with a processing compound.

6. Prior to installing a new unit on the engine, deprocess it and check the respective Service Log or certificate.

7. Do not use old locks or gaskets, when installing new units and assemblies on the engine.

8. When replacing units and assemblies, use another wrench to hold pipe connections against slackening, while unscrewing union nuts.

Prior to installing pipelines, blow their nuts and connections with compressed air; treat all threaded joints on the pipelines with petrolatum. Never use other lubricants.

9. When carrying out external deprocessing of the engine accessories, do not remove transportation plugs. They must be removed only before making respective connections.

10. Accessory attachment clamp halves should be installed in sets, the halves of each clamp being arranged definitely relative to each other. The end faces of each clamp half are marked with identical numbers. When installing a clamp, take

care to see that its surfaces fit properly. After tightening up the clamp bolts, a gap must be provided in the clamp end joints. The gaps in the joints of each clamps should not differ more than by 0.5 mm from each other.

11. When replacing flow restrictors, inspecting filters or repairing leaky pipeline connections on fuel system units, do not fail to replace sealing rings by new ones.

12. Make an entry into the engine Service Log to any replacement of engine unit or accessory.

LIST OF UNITS AND ASSEMBLIES ALLOWED TO BE REPLACED DURING OPERATION

(a) Engine Units

1. Fuel booster pump ДЦН-44-П3Т
2. Fuel regulating pump НР-30
3. Centrifugal governor ЦР-1В
4. Centrifugal governor ЦР-2В
5. Over temperature amplifier УРТ-19А-2Т
6. Twin thermocouples Т-99-1
7. Main oil pump ОМН-30
8. Oil scavenging pump МНО-30
9. Oil filter МФС-30
10. Centrifugal deaerator ЦВО-ФС-30
11. Centrifugal breather ЦС-30
12. Ignition unit СКНА-22-2А
13. Ignition plugs СП-06ВП
14. Starter-generator СТГ-12ТВМО
15. Automatic starting control unit АПД-19БД (series II)
16. Fire detectors ДП-6
17. Ice detector ДО-202М
18. Electric actuator МП-5М with deicing system shut-off valve
19. Pressure warning unit СДУ2-0,15
20. Solenoid-operated valve М782000

CAUTION. When removing engine units for inspection or replacement, do not bend or twist the ends of pipes. For the sake of proper fitting, slacken the union nut from the pipeline opposite end, if necessary.

(b) Engine Assemblies

1. The primary fuel manifold
2. The main fuel manifold
3. Fuel burners ФР-30ДС
4. The butterfly valves and hydraulic actuators for bleeding air aft of the 5th or 10th stage of compressor high-pressure section
5. The air blow-off shutter actuators aft of the 4th and 5th stages of compressor high-pressure section
6. The variable IGV actuator
7. The drain tank

8. Terminal switch AB12K indicating the position of inlet guide vanes
9. The exhaust unit jet nozzle
10. The exhaust unit sleeve
11. The exhaust tail cone
12. The exhaust unit flow mixer
13. The air blow-off valve aft of the 10th stage of compressor high-pressure section
14. The external oil, fuel, air, instrument, and electric lines, as well as their attachment fittings.

(c) Aircraft Accessories

Piston-type rotary pump НП43-1 or НП43М-1

Notes: (a) replacement of engine units and assemblies under field conditions is to be done only by representatives of the engine Manufacturing plant;
(b) after completing replacement of engine units, assemblies or parts, try out the engine and inspect it visually after shut-down. If necessary, adjust engine accessory units as instructed in the respective sections of Chapter VIII;
(c) aircraft accessories installed on the engine must be replaced by the user.

A. REPLACEMENT OF UNITS

1. Replacement of Fuel Booster Pump ДЦН-44-П3Т

1. Unlock and screw off the nuts securing the inlet connection; remove the durite sleeve from the fuel outlet connection.
2. Disconnect the drain pipes.
3. Unlock and screw out the bolts coupling the pump attachment strap.
4. Dismantle the pump and subject it to anti-corrosion treatment.
5. Install new pump ДЦН-44-П3Т in the reverse order of dismantling. Apply a torque of 1.5 to 2.0 kgm to tighten up the clamp bolts of pump ДЦН-44-П3Т.
6. Start the engine two times. Check fuel pressure before fuel regulating pump HP-30 and check the operation of booster pump ДЦН-44-П3Т by smoothly accelerating the engine to normal rating.

2. Replacement of Fuel Regulating Pump HP-30

1. Disconnect the durite sleeve from the fuel pump inlet connection.
2. Disjoin the plug connector of the cable running to electromagnet 3МТ-243 incorporated in the overtemperature limiter.
3. Unlock and disconnect the fuel inlet and outlet pipes as well as the air supply pipeline from the starting fuel control unit.
4. Unlock and disconnect the fuel outlet pipes running to centrifugal governors ЦР-2В and ЦР-1В.
5. Unlock and disconnect fuel drain pipes.
6. Unlock and disjoin the control link from the fuel regulating pump control lever.
7. Unlock and undo the bolts tightening the pump attachment clamp.

8. Remove the fuel regulating pump. Remove the pump inlet connection.

9. Deprocess new fuel regulating pump HP-30 and install it in position in the reverse order of dismantling. Apply a torque of within 3.5 - 4.5 kgm for tightening the bolts of the fuel regulating pump clamp.

Note: Prior to installing new fuel regulating pump HP-30 on the engine do not fail to measure the insulance of electromagnet ЭМТ-243 incorporated in the overtemperature limiter.
The resistance of the circuit should be within 18 - 25 ohms as measured between plug connector pins No.1 and No.2.
The insulance measured by a megger between plug connector pins No.1 and No.2 and the pump body must be not less than 20 megohms.

10. Start the engine two times for checking the automatic starting fuel control unit of the fuel regulating pump.

Measure idle rpm, compressor high-pressure rotor speed at maximum take-off rating, turbine outlet gas maximum temperature, speed limit controlled by the ПРТ-35 system and engine acceleration characteristics. Check the fuel regulating pump for steady operation at various ratings in compliance with Fig.39 and Section "Engine Warming-Up and Trial" given in Chapter III. In case of need, adjust compressor high-pressure rotor speed and maximum fuel flow at maximum take-off rating, acceleration time, turbine outlet gas maximum temperature and speed value restricted by overtemperature control system ПРТ-35. In flight check the engine operating parameters at maximum take-off rating as instructed in Chapter VIII.

11. Treat removed fuel regulating pump HP-30 with anti-corrosion compound.

3. Replacement of Centrifugal Governor ЦР-1Б

1. Unlock the coupling nuts on all the fuel inlet and outlet pipes.

2. Screw off the union nut of the pipe supplying fuel pressure from the hydraulic decelerator incorporated in fuel regulating pump HP-30.

3. Unscrew the union nut of the fuel return pipe from centrifugal governor ЦР-2Б.

4. Undo the union nut of the pipe running to the panel for measuring fuel pressure at the inlet to fuel regulating pump HP-30.

5. Unscrew the nut of the pipe serving for fuel return into the HP-30 fuel regulating pump.

6. Screw off the union nut of the drain pipe of centrifugal governor ЦР-1Б.

7. Unbend the locks and screw out the bolts tightening the ЦР-1Б centrifugal governor attachment clamp.

8. Remove the ЦР-1Б centrifugal governor and treat it with anti-corrosion compound.

9. Deprocess and install new centrifugal governor ЦР-1Б in the reverse order of dismantling. Apply a torque of 1.5 - 2 kgm for tightening up the clamping bolts of centrifugal governor ЦР-1Б.

10. Check centrifugal governor ЦР-1Б for proper operation on the ground following the Chart in Fig.39 and Section "Engine Warming-Up and Trial" of Chapter III.

Adjust compressor low-pressure rotor limit speed as instructed in Chapter VIII.

4. Replacement of Centrifugal Governor ЦР-2В

1. Unlock the union nuts on all the fuel inlet and outlet pipes.

2. Unlock and uncouple the plug connector supplying power to the starter-generator switch.

3. Screw the union nut off the fuel return pipe connected to centrifugal governor ЦР-1В.

4. Screw the union nuts off the connections for fuel supply to the hydraulic actuators controlling the air blow-off shutters and variable incidence inlet guide vanes.

5. Screw the union nut off the pipe supplying high-pressure fuel to fuel regulating pump НР-30.

6. Screw the union nut off the drain pipe.

7. Unbend the locks and back out the tightening bolts of the ЦР-2В centrifugal governor attachment clamp.

8. Remove centrifugal governor ЦР-2В and subject it to anti-corrosion treatment.

9. Deprocess and install new centrifugal governor ЦР-2В. Apply a torque of 1.5 - 2.0 kgm for tightening the bolts of the governor strap.

10. Check the starter-generator disengagement speed and the speed at which the air blow-off shutters aft of the 4th and 5th stages of the compressor high-pressure section close and the IGVs thereof change over their position. Check the operation of centrifugal governor ЦР-2В in conditions set forth by the Chart in Fig.39 and described in Section "Engine Warming-Up and Trial" of Chapter III. If necessary, carry out readjustments of the ЦР-2В unit as instructed in Chapter VIII.

5. Replacement of Overtemperature Amplifier УРТ-19А-2Т

1. Unlock and disjoin the plug connectors of the wires running to the block of thermocouples Т-99-1, supplying power to overtemperature control system ПРТ-35 and leading to overtemperature limiter incorporated in fuel regulating pump НР-30.

2. Unbend the locks and undo the bolts fastening amplifier УРТ-19А-2Т to the aircraft panel.

3. Remove amplifier УРТ-19А-2Т and install a new one, following the reverse order of dismantling.

When replacing amplifier УРТ-19А-2Т, do not fail to check that the calibration group of thermocouples Т-99-1 installed on the engine correspond to that of adjusted amplifier УРТ-19А-2Т. If otherwise, manipulate the presetter of amplifier УРТ-19А-2Т (see Fig.49) to set the required calibration group of the amplifier in accordance with the calibration group of thermocouples Т-99-1. To do this, open the presetter cover on amplifier УРТ-19А-2Т and shift the dial so that its notch be in line with one of the calibration group divisions marked with I, II and III that corresponds to the calibration group of thermocouples Т-99-1 installed on the engine.

4. Run the engine at maximum take-off rating to check the operation of overtemperature control system ПРТ-35 limiting maximum permissible temperature aft of the engine turbine. To do this, follow the procedure set forth in Section "Engine Warming-up and Trial" of Chapter III.

If needed, readjust the overtemperature limiter as advised in Chapter VIII.

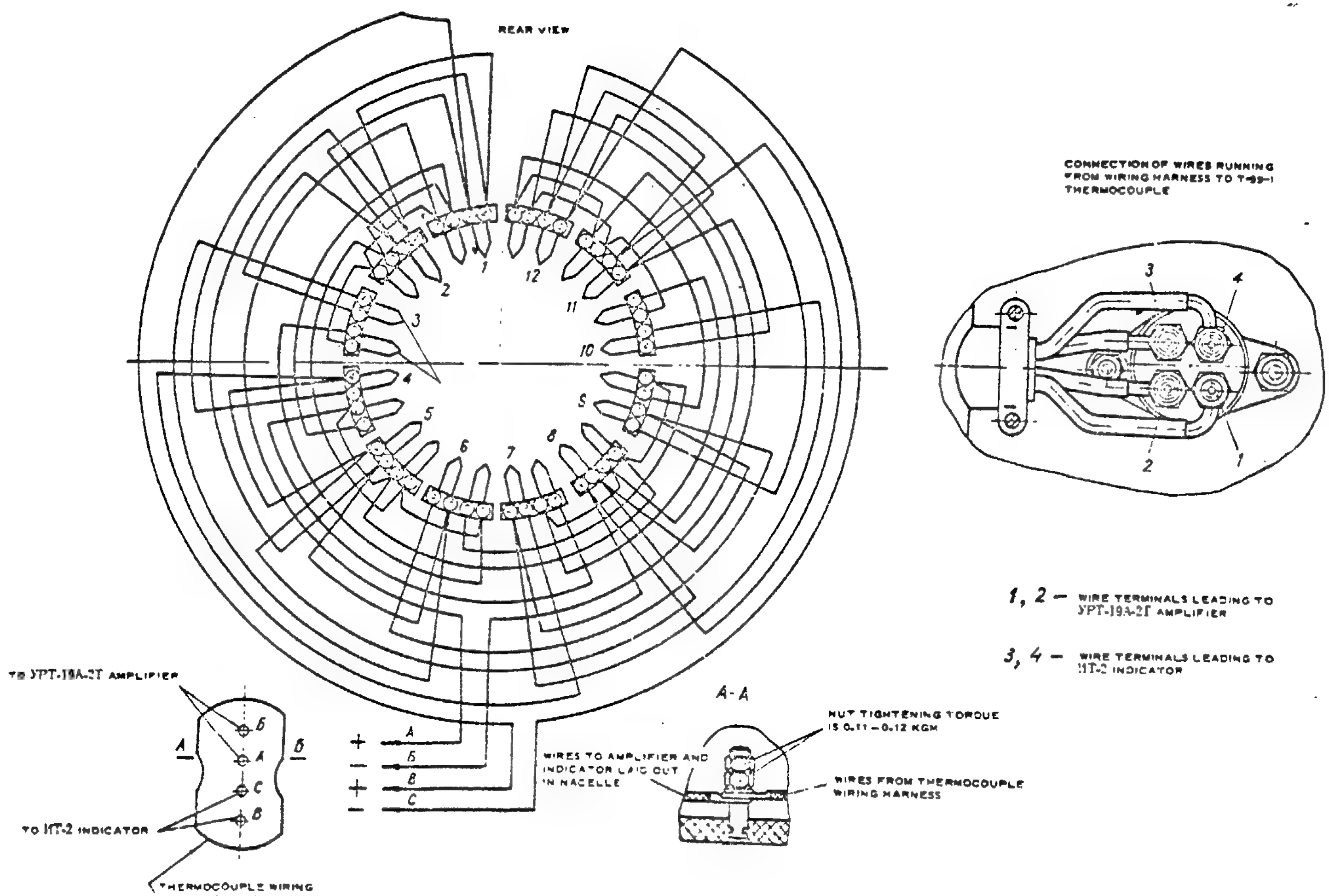

FIG. 52. T-99-1 THERMOCOUPLE CONNECTION WIRING DIAGRAM

6. Replacement of Main Thermocouples T-99-1

1. Unlock and undo the bolts fastening the exhaust unit inner cone and remove the cone.

2. Use a special wrench available in the tool kit to unscrew the self-locking nuts fastening the wire harness to the thermocouples.

3. Undo the bolts fastening the thermocouples to their brackets and take off the thermocouples.

4. Install new thermocouples T-99-1, drive in and lock the thermocouple attachment bolts. Prior to installing the thermocouples on the engine, do not fail to check the hot junctions and wires of each thermocouple for condition (the circuits between contacts 1 - 2 and 3 - 4 should not be broken, see Fig 52), the thermocouple wires for short-circuits and insulance.

The insulance must be not less than 0.5 megohm for new thermocouples and at least 20,000 ohms for thermocouples that have accumulated 300 operating hours.

5. Connect the wire lugs to thermocouples T-99-1. Take care that the digits stamped on the wire lugs correspond to those punched on the thermocouple flanges (Fig.52). Put washers on the thermocouple pins and screw down the self-locking nuts; tighten up the nuts with the use of a special torque wrench applying an effort of not more than 0.20 kgm.

Before screwing the nuts on the pins, coat the nut threading with [illegible] BHNHH-225 (Specification [illegible]-MT12-6[illegible]). It is used the [illegible]-77 oil.

6. Mount the exhaust unit inner cone, having coated the cone attachment bolts with compound "[illegible]".

7. The replacement of thermocouples T-99-1 over, ascertain [illegible] the [illegible] group of the new thermocouples corresponds to that of amplifier [illegible]-2[illegible] [illegible] the amplifier, if necessary, as instructed in this chapter under Section "[illegible] of Overtemperature Amplifier [illegible]". The position of the [illegible] selector of indicator [illegible]-2 [illegible] also correspond to the calibration group of the newly installed thermocouples.

Note: The engine may be [illegible] with thermocouples T-99-1 of calibration groups [illegible].

8. After replacing the thermocouples check them for proper functioning in accordance with the Chart in Fig. 49 which is an illustration to Section "Engine Warming-Up and Trial" of Chapter III; check the operation of the [illegible]-35 overtemperature control system limiting turbine outlet gas temperature. Readjust the system, if necessary, observing the instructions of Chapter VIII.

7. Replacement of Main Oil Pump [illegible]

1. Unlock and back out the bolts holding the oil pump to the lower [illegible] gear box. Take off the washers.

2. Remove the oil pump and subject it to anti-corrosion treatment.

3. Depreserve and install new oil pump [illegible]-30. Apply a torque of 1.5 - [illegible] kgm for tightening the oil pump attachment bolts.

Note: The pressure control and non-return valves of the oil pump [illegible] ed, if necessary.

4. Measure oil pressure at the engine inlet during motoring over, [illegible] gradual acceleration of the engine from idle to normal rating rpm. [illegible]

ne oil filter. Adjust the engine inlet oil pressure, as instructed in ter III.

5. Prior to motoring the engine over after replacing the oil pump, do not fail leed air from the oil supply main line, for which purpose unscrew a special on the oil pump housing.

8. Replacement of Oil Scavenging Pump MHO-30

1. Unlock and unscrew the nuts off the pipes serving for scavenging oil from shaft tube cavity and rear support void.
2. Remove the oil scavenge pipes and wash the filters.
3. Unscrew the pump attachment self-locking nuts.
4. Remove the pump and subject it to anti-corrosion treatment.
5. Deprocess and install new oil scavenging pump MHO-30 in the reverse order ismantling. Apply a torque of 1.6 - 2.2 kgm for tightening the nuts by a torque ich.
6. Check the engine for proper running by gradually accelerating it from idle ormal rating rpm, then inspect the engine for oil leaks.

9. Replacement of Centrifugal Deaerator HBO-CC-30

1. Disjoin the chip-detecting filter plug connector.
2. Unlock and undo the union nuts of pipes carrying oil from the deaerator to adaptor annular oil cooler.
3. Undo the nuts securing deaerator HBO-CC-30 to the lower drive gear box.
4. Remove the deaerator and subject it to anti-corrosion treatment.
5. Deprocess and install new deaerator HBO-CC-30 in the reverse order of antling.
6. Check the operation of the engine by gradually accelerating it from idle to al rating rpm.

After shutting the engine down check the amount of oil drained from the engine measure the oil level in the oil tank.

10. Replacement of Centrifugal Breather ЦС-30

1. Unlock and screw off the nuts coupling the breathing pipes to the centrifu- breather.
2. Remove the breathing pipe up to the joint.
3. Unscrew the self-locking nuts holding the centrifugal breather to the upper re gear box.
4. Remove the centrifugal breather and subject it to anti-corrosion treatment.
5. Deprocess and install a new centrifugal breather in the reverse order of antling.
6. Check the engine operation by gradually accelerating it from idle to normal ing rpm.

11. Replacement of Ignition Unit СКН-22-2А

1. Unlock and uncouple the plug connectors of the ... voltage supply wires and ignition plug high-voltage wires.

2. Unbend the locks on the bolts holding unit CKHA-22-2A to the engine.

3. Back out the bolts securing ignition unit CKHA-22-2A.

4. Remove the ignition unit.

5. Install new ignition unit CKHA-22-2A in the reverse order of dismantling.

6. Start the engine two times for checking the operation of the engine ignition system.

Note: Ignition units CKHA-22-2A incorporate apparatus P-22 containing a radioactive isotope - a beta-radiator. Radiation protection is ensured by means of glass, aluminium and outside casings of the unit. The radiation flux does not exceed the natural background radiation level. The use or storage of the ignition unit is not hazardous for maintenance personnel. The ignition units should not be discarded or destructed by users.

In case of damage to the outside casing of the unit, the latter must be encased into an aluminium container with a wall thickness of 0.8 - 10 mm to be stored or transported. The container should bear a radiation hazard mark. The container with the defective unit must be kept in special laboratory or a safe till it is forwarded to the Manufacturing plant. The safe must also bear a radiation hazard mark.

12. Replacement of Ignition Plug СП-06ВП

1. Unlock and remove the union nut on the sheath of the wire running from ignition unit CKHA-22-2A to the ignition plug.

2. Unlock the ignition plug attachment bolts.

3. Unscrew the bolts and remove the ignition plug.

4. Install a new ignition plug, using the procedure in the reverse order of dismantling.

5. Start the engine two times for checking the operation of the engine ignition system.

13. Replacement of Starter-Generator СТГ-12ТВМО

1. Disconnect the electric wiring terminals.

2. Detach the air cooling duct connection.

3. Unlock and unscrew two bolts tightening the starter-generator strap.

4. Holding the starter-generator by hand, remove the attachment strap and take off the starter-generator.

5. Unlock and undo the bolts securing the adapter to the starter-generator and remove the adapter.

6. Attach the adapter to the starter-generator to be installed anew, fasten it by means of the bolts and lock the bolts.

7. Install the new starter-generator on the engine, using the reverse order of dismantling.

Use a 3.5 - 4.5 kgm torque wrench for tightening the strap bolts.

8. Start the engine and make sure the starter-generators function properly both in the starting and in generating modes of operation.

14. Replacement of Automatic Starting Control Unit АПД-19ВП (series II)

1. Uncouple the starting system wiring plug connectors from automatic starting control unit АПД-19ВП (series II).

25X1

2. Unbend the locks and undo the bolts fastening the unit to the engine nacelle
3. Remove the automatic starting control unit АПД-19БД (series II).
4. Install new unit АПД-19БД (series II) in the reverse order of dismantling.
5. Blow out and start the engine to check the engine starting system for proper operation.

15. Replacement of Fire Detectors ДП-6

1. Uncouple the plug connector.
2. Unlock and undo the fire detector.
3. Install a new fire detector in the reverse order of dismantling.
4. Check the fire detector circuit for condition by pressing the test button for a short while. As soon as the button is released, the indicating lamp must flicker on and off.
5. Measure the resistance in the ДП-6 fire detector circuit up to the plug connector of the actuating unit. The resistance must be not over 3.5 ohms.

16. Replacement of Ice Detector ДО-202М

1. Disjoin the plug connector.
2. Unlock and unscrew the union nut connecting the air supply pipe to solenoid-operated valve М782000.
3. Undo the ice detector attachment nuts.
4. Remove the ice detector.
5. Mount a new ice detector, following the procedure in the reverse order of dismantling. Apply a torque of within 1 - 1.2 kgm for tightening the ice detector attachment nuts.

17. Replacement of Solenoid-Operated Valve М782000

1. Uncouple the plug connector.
2. Unlock and screw off the union nuts from the air inlet and outlet pipe connections.
3. Screw off the nut securing the tightening bolt of the valve holding strap. Dismount valve М782000.
4. Mount new solenoid-operated valve М782000, using the procedure in the reverse order of dismantling.

18. Replacement of Pressure Warning Unit СДУ2-0,15

1. Uncouple the plug connector.
2. Unlock and unscrew the union nut of the pipeline supplying air to solenoid-operated valve М782000.
3. Unlock and screw off the nut fastening the pressure warning unit to the bracket; remove the pressure warning unit.
4. Install a new pressure warning unit, using the procedure in the reverse order of dismantling.

Note: Upon replacing ice detector ДО-202М, solenoid-operated valve М782000 or pressure warning unit СДУ2-0,15 check the operation of the ice warning system by smoothly accelerating the engine from idle to normal rating speed.

25X1

If the ice warning system is sound and ice detector ДО-202И is not under icing conditions, the indicating light should not come on. When the ice warning system is switched on at n_2 = 4500 ± 200 rpm (37 - 40%), the indicating light may come on for a short while.

19. Replacement of Electric Actuator МП-5М with Deicing System Shut-Off Valve

1. Uncouple the plug connector.
2. Unlock and screw off the nuts from the bolts holding the air supply pipes upstream and downstream of the shut-off valve, disconnecting the pipeline that supplies air to heat the inlet guide vanes.
3. Undo the nuts fastening the shut-off valve to the bracket.
4. Remove the shut-off valve complete with electric actuator МП-5М.
5. Mount a new shut-off valve complete with electric actuator МП-5М, following the procedure in the reverse order of dismantling.
6. Check the operation of electric actuator МП-5М and the shut-off valve by switching on the air bleed system for heating the compressor low-pressure section IGVs at normal rating two times.

B. REPLACEMENT OF ENGINE ASSEMBLIES

20. Replacement of Primary Fuel Manifold

1. Back off the nuts of the clamping strips holding the fuel supply branch pipes running from the primary and main fuel manifolds.
2. Unlock and screw off the union nuts of the branch pipes delivering fuel to burners from the primary and main fuel manifolds (both at the manifold and burner ends). Remove the branch pipes together with the clamping strips.
3. Unlock and undo the union nut of the pipeline used for measuring pressure in the primary fuel manifold.
4. Take off the clamping blocks of the pipelines running from fuel regulating pump НР-30 to the primary and main fuel manifolds.
5. Unlock and screw off the union nut of the fuel supply pipeline from fuel regulating pump НР-30 to the primary fuel manifold.
6. Release the locks and back out the nuts holding the primary and main fuel manifold pipelines to the struts. Remove the plain and spherical washers as well as the upper halves of the clamping blocks.
7. Unlock and screw off the union nuts of the primary fuel manifold upper and lower joints. Remove the primary fuel manifold.
8. Install a new primary fuel manifold, using the procedure in the reverse order of dismantling.

To properly align the pipelines and prevent them from overstrain, use may be made of adjusting washers 3406A (1 - 3)-8-16 (passivated) which must be placed under the spherical washers of the lower halves of the clamping blocks. To ensure reliable cotter-pinning of the tightening nut, provision is made for installation of an adjusting washer between the nut and the spherical washer of the upper half of the clamping block.

9. Check the pipeline joints for leakage, while performing a "false" start and during operation of the engine at all the ratings.

21. Replacement of Main Fuel Manifold

1. Back off the nuts of the clamping strips holding the fuel supply branch pipes running from the primary and main fuel manifolds.

2. Unlock and screw off the union nuts of the branch pipes delivering fuel to burners from the primary and main fuel manifolds (both at the manifold and burner ends).

3. Take off the clamping blocks of the pipelines running from fuel regulating pump НР-30 to the primary and main fuel manifolds.

4. Unlock and screw off the union nut of the fuel supply pipe-line from fuel regulating pump НР-30 to the main fuel manifold.

5. Release the locks and back out the nuts holding the primary and main fuel manifold pipelines to the struts. Remove the plain and spherical washers as well as the upper halves of the clamping blocks.

6. Unlock and screw off the union nuts of the main fuel manifold upper and lower joints. Remove the main fuel manifold.

7. Install a new main fuel manifold, using the procedure in the reverse order of dismantling.

If necessary, place adjusting washers under the lower nut of the clamping block upper half, as advised in Item 8 of Subsection 20.

8. Check the pipeline joints fore leakage, while performing a "flase" start and during engine operation at all the ratings.

22. Replacement of Fuel Burners ФР-30ЛС

When replacing separate burners, see that new burners are equal in flow capacity to the old ones (each burner carries the specific capacity group stamp).

If several burners are to be replaced, do not remove the next burner until the previous new one is finally installed. Replacement of burners is accomplished in the following sequence:

1. Back off the nuts of the clamping strips holding the fuel supply branch pipes running from the primary and main fuel manifolds.

2. Unlock and screw off the union nuts of the branch pipes delivering fuel to burners from the primary and main fuel manifolds. Remove the branch pipes complete with the clamping strips.

3. Unlock and back out the burner securing bolts.

4. Remove the burner and the gasket.

5. Install a new gasket on a new burner, carefully introduce the burner into the combustion chamber ferrule, align the bolt holes in the burner flange, in the gasket and in the combustion chamber diffuser flange.

6. Coat the burner fastening bolt screw with compound "жс" drive the bolts into the combustion chamber diffuser holes and lock the bolts.

7. Install the branch pipes delivering fuel to the burners from the primary and main fuel manifolds complete with the clamping strips, using the procedure in the reverse order of dismantling.

8. Check the pipeline and connection joints for leakage, while performing a "false" start and during engine operation at all the ratings.

23. Replacement of Butterfly Valve and Its Actuator Used for Bleeding Air From 5th and 10th Stages of Compressor High-Pressure Section

1. Disconnect the aircraft air bleed system and the pipelines supplying hot air to the IGVs from the butterfly valve body.

2. Unlock and undo the nuts fastening the air bleed duct aft of the 5th stage of the compressor high-pressure section. Remove the air bleed duct.

3. Unlock and unscrew the bolts fastening the air bleed duct aft of the compressor 10th stage to the rear casing. Remove the air bleed pipe complete with its duct, having disconnected the union nut holding the pipe to the butterfly valve body.

4. Release the lock and screw off the union nut connecting the fuel supply pipeline to the butterfly valve actuator.

5. Undo the self-locking nuts fastening the air bleed butterfly valve to the load-carrying ring.

6. Remove the air bleed butterfly valve and treat it with anti-corrosion compound from the outside.

7. Deprocess and install a new butterfly valve, using the procedure in the reverse order of dismantling.

8. Check the pipeline and hydraulic actuator connection joints for leakage, while performing a "false" start of the engine. Check the engine for proper operation, smoothly accelerating it from idle to normal rating speed.

24. Replacement of Actuating Cylinder Controlling Air Bleed Valves Aft of 4th and 5th Stages of Compressor High-Pressure Section

1. Unlock and screw off the union nuts holding the pipelines to the air bleed valve hydraulic actuator inlet and outlet connections, undo the fuel connection and drive a dummy bolt instead of it.

2. Unlock and screw out the bolts fastening the hydraulic actuator cylinder to the forward casing.

3. Drive in the dummy bolt to displace the piston inside the hydraulic actuator to open the air bleed valves. Disconnect the hydraulic actuator rod from the valve control lever and remove the actuator.

4. Install a new air bleed valve actuator, proceeding as follows:

(a) unscrew the fuel supply connection from the hydraulic actuator cover, without fastening the hydraulic actuator to the forward casing flange, then screw in a dummy bolt instead by hand until it contacts the piston (measure the protrusion of the bolt relative to the cover). Drive in the dummy bolt to shift the piston towards opening position of the air bleed valve;

(b) set the air bleed valves in the closed position and connect the actuator piston rod with the air bleed valve control lever;

(c) unscrew the dummy bolt to a degree to ensure its protrusion relative to the cover as measured in accordance with Item (a), then bolt the hydraulic actuator to the forward casing flange and lock the bolts. The dummy bolt must be given from 4 to 9 complete turns from the above set position to contact the piston. Otherwise, the

connection of the piston rod with the air bleed valve control lever is not guaranteed;

(d) after the hydraulic actuator controlling the air bleed valves is installed on the engine, adjust the piston travel, proceeding as follows:

- drive the dummy bolt in the cylinder cover by hand until it comes in contact with the piston;

- turn the dummy bolt into the cover again to displace the piston by 15 ± 0.5 mm from the previous position and secure the new position of the piston by means of the adjusting bolts located on the cylinder;

- this done, lock the nuts of the adjusting bolts and screw off the dummy bolts from the actuating cylinder cover;

- drive the fuel supply connection in the cover;

(e) couple the pipeline union nuts with the actuator inlet and outlet connections, tighten the union nuts up and lock them.

5. Check the pipeline and hydraulic actuator connection joints for leakage, while performing a "false" start of the engine. Check the engine for proper operation by smoothly accelerating it from idle to normal rating speed.

25. Replacement of Compressor High-Pressure Section IGV Actuator

1. Unlock and screw off the union nuts connecting the fuel supply pipelines to the IGV actuator.

2. Unlock and back out the bolts fastening the hydraulic actuator flange to the bracket.

3. Release the lock and screw off the nut from the bolt coupling the hydraulic actuator rod to the IGV control link. Remove the hydraulic actuator.

4. Install a new hydraulic actuator, observing the following procedure:

(a) withdraw the IGV control link upwards to the utmost;

(b) connect the hydraulic actuator rod with the IGV control link without tightening the connecting bolt with its nut and fastening the hydraulic actuator to the bracket flange;

(c) measure the clearance between the flanges of the hydraulic actuator and bracket. It must be within 1.67 ± 0.1 mm, which corresponds to the position of the IGVs at +2 deg.

In case the clearance differs from the specified value, it is necessary to disconnect the rod and the link and adjust the clearance as required by changing the link length;

(d) connect the hydraulic actuator rod with the link finally and fasten the actuator to the flange, having seated it onto the flange. As soon as the hydraulic actuator is pressed against the locating flange and the clearance 1.67 ± 0.1 mm is taken up, the IGVs get installed to the zero degree position;

(e) connect the fuel pipelines, lock the union nuts and check the pipeline connections for leakage, while performing a "false" start of the engine.

5. Gradually run up the engine to 0.7 normal rating to check the IGV actuator for proper functioning by observing the indicating light coming on and going out.

[redacted]

26. Replacement of Microswitch A812K of IGV Position Transmitter

1. Uncouple the sheathed wire plug connector.

2. Unlock and screw off the bolts fastening the IGV position transmitter to the bracket and remove the transmitter.

3. Undo the screws holding the transmitter plastic cover and remove the cover.

4. Back out the screws fastening the transmitter plug connector wires to the microswitch terminals and disconnect the wires.

5. Undo the screws used for attachment of the transmitter plug connector to the housing and uncouple the plug connector from the housing.

6. Take the faulty microswitch out of the transmitter housing together with the rubber gasket.

7. Install a new microswitch in the transmitter housing, observing the procedure in the reverse order of dismantling and taking into consideration the fact that wire No.1 of the plug connector must be joined with terminal "O" and wire No.2 - with terminal "H3".

8. Connect test lamp СЛМ-1 and a 27 V ± 10% power source or a flash-light lamp with battery КБС-Л-0.50 to the transmitter plug connector. The lamp should light up until the transmitter is installed on the engine.

9. Take up the play of the IGV position indicator pointer in the direction off the bracket and install the transmitter in position. As a result, the indicating lamp must go out.

10. Apply an effort of 5 to 7 kg to the indicator pointer in the direction off the transmitter. The indicating lamp should not come on.

<u>Note</u>: Should the indicating lamp light up, undo the transmitter bracket-to-engine attachment bolts and, having replaced the bolt locks, reinstall the bracket together with the transmitter on the engine without tightening up the attachment bolts. Having taken up the indicator pointer play in the direction off the transmitter, move the transmitter towards the pointer until the microswitch operates (the indicating lamp goes out) and then move it additionally in the same direction by 1 ± 0.2 mm. Check the indicator transmitter for proper installation by applying the above specified effort to the indicator pointer, as advised under Item 10.

11. Drive in and lock the bolts fastening the transmitter bracket to the engine, disconnect the test lamp and connect the indicator transmitter to the engine electric wire harness.

12. Align the zero division on the transmitter housing scale with the IGV indicator pointer, then secure and lock with safety wire the scale fastening screws.

13. Check the engine for proper functioning by smoothly accelerating it to 0.7 normal rating and check the operation of the IGV actuating mechanism by reference to the indicating lamp which must come on and go out in proper time.

27. Replacement of Drain Tank

1. Unlock and disconnect all the pipelines running to the drain tank.

2. Unlock and screw out the bolts holding the drain tank to the lower drive gear box.

3. Dismantle the drain tank.

4. Install a new drain tank in the reverse order of dismantling.

5. Check the pipeline joints for leakage, while performing a "false" start and during engine operation at idle speed.

28. Replacement of Jet Nozzle

1. Undo the bolts fastening the jet nozzle flange to the exhaust unit flange.
2. Remove the jet nozzle.
3. Install a new jet nozzle, having paid particular attention to the condition of the gasket glued to the jet nozzle flange. If the gasket is damaged, detach it from the flange and cement a new one to the flange, using glue 9М-35 for that purpose.

The jet nozzle is attached by means of bolts 3156А-6-16 (passivated) and self-locking nuts 3373А-6КД.

29. Replacement of Exhaust Unit

1. Remove the jet nozzle, as instructed above.
2. Disconnect the drain hose and the engine breathing system pipeline.
3. Unlock and back off the union nut of the breathing pipeline and remove the breathing pipeline rear connection.
4. Undo the bolts fastening the drain hose clamps and remove the hose.
5. Detach the thermocouple wire lead-out block, having disconnected the wire terminals.
6. Unlock and screw out the bolts fastening the exhaust unit to the outer rear casing flange of the combustion chamber and remove the exhaust unit.
7. Use compound "ХС" to coat the threading of the exhaust unit attachment bolts. Apply a thin layer of silicone enamel to the mating surfaces of the flanges belonging to the new exhaust unit and combustion chamber aft casing. Wait for 4 to 8 minutes. Apply another layer of silicone enamel to the same surfaces and wait for 4 to 8 minutes again.
8. Mount the new exhaust unit in accordance with mark "0" in the reverse order of dismantling.
9. Install the jet nozzle.
10. Check the engine operation in full compliance with the Chart in Fig.39 and Section "Engine Warming-Up and Trial" of Chapter III.

30. Replacement of Exhaust Unit Inner Cone

1. Unlock and undo the inner cone-to-thermocouple housing flange attachment bolts.
2. Remove the inner cone.
3. Coat the bolt threading with compound "ХС".
4. Install a new inner cone.

31. Replacement of Exhaust Unit Mixer

1. Remove the jet nozzle, as instructed above.
2. Unlock and back out the radial bolts fastening the flow mixer. Withdraw the bolts and remove the mixer.

3. Treat the bolt threads with compound "ZC".

4. Install a new flow mixer in the reverse order of dismantling.

5. Check the operation of the engine in full compliance with the Chart in Fig.39 and Section "Engine Warming-Up and Trial" of Chapter III.

32. Replacement of Air Blow-Off Valve Aft of 10th Stage of Compressor High-Pressure Section

1. Unlock and screw off the union nuts of the air blow-off pipes.

2. Unlock and unscrew the bolts fastening the air blow-off valve cover, take off the cover and remove the valve.

3. Install a new valve and the cover.

4. Drive in and lock the valve cover attachment bolts.

5. Screw on and lock the union nuts of the air blow-off pipes.

6. Check the operation of the air blow-off valve, while starting the engine.

33. Replacement of Pipelines and Hoses

Whenever replacing pipelines on the engine, observe the following requirements:

1. Prior to removing pipelines and hoses, dismantle their attachment clamps and straps.

2. After disconnecting the pipelines and hoses from their connections, fit the connections, pipes and hoses with plugs.

3. Before installing pipelines and hoses on the engine, wash them in clean gasoline, clean all the metallic attachment points of the pipelines and hoses until bright and degrease them with acetone to provide for reliable electric contact.

4. The pipelines and hoses should be free of twisting, corrosion, burrs, heavy notches and dents.

5. All pipelines and hoses should be erected on the engine so that no stresses are developed; when fitting them onto the connections, the pipe union nuts must be capable of being screwed onto the connections by hand.

Prior to installing pipelines and hoses coat their threaded connections with petrolatum and coat the threads of the clamp and strip attachment studs or bolts with compound "ZC".

When coating the connection threads with petrolatum, protect the connection cones and its mating part of the pipe or hose from smearing with petrolatum, to ensure reliable electric contact between the parts.

6. While erecting pipelines and hoses on the engine, ensure a clearance of not less than 3 mm between the pipelines and adjacent parts. A clearance of not less than 1.5 mm is allowed only between intersecting pipelines and in certain locations at a length of not over 50 mm before and after clamps.

7. When installing clamps and blocks on the pipes and hoses, see that they fit freely to them on entire surface.

8. Tighten up the nuts by applying moderate efforts, after which lock the nuts.

9. Check the newly installed pipelines and hoses for leakage, while performing a "false" start and during operation of the engine at 0.7 normal rating speed.

34. Replacement of Low-Voltage Wire Harness

1. Unlock and uncouple the plug connectors of all the sheathed wires of the harness.

2. Disconnect the sheathing conduit attachment clamps, release the wire harness attachment blocks.

3. Unlock and screw out the union nuts in the wire harness conduit joints.

4. Undo the screws and withdraw the master plug connector from the hole in the engine measuring instrument transmitter panel bracket.

Remove the wire harness.

5. Install a new wire harness in the reverse order of dismantling.

Note: (a) prior to installing the wire harness, clean the block attachment points bright to ensure proper electric contact between the mating parts;
(b) the wire harness must be installed with the conduit union nuts disjointed;
(c) before connecting the plug connectors of the sheathing conduits do not fail to measure the insulance of the wires. The insulance should be not less than 20 megohms.

6. Check the operation of the starting and power supply system with the engine running from idle through normal rating speed.

C. REPLACEMENT OF AIRCRAFT ACCESSORIES

35. Replacement of Piston Pump НП43-1 (НП43М-1).

1. Disconnect the rubberized fabric sleeve from the oil inlet connection of the piston pump.

2. Disconnect the high-pressure and drain pipelines.

3. Unlock and undo two bolts fastening the piston pump straps.

4. Hold the pump by hand, while detaching the attachment straps and removing the piston pump. Process the removed pump.

5. Install a new piston pump in the reverse order of dismantling. Use a 3.5 - 4.5 kgm torque wrench for tightening up the clamping bolts.

6. Start the engine and make sure the piston pump functions properly when idle or loaded.

INSTALLATION OF ENGINE ON AIRCRAFT

Chapter X

INSTALLATION OF ENGINE ON AIRCRAFT

1. UNPACKING AND EXTERNAL DEPROCESSING OF ENGINE

At the Manufacturing plant the engine is packed in a sealed polivinyl chloride cover. Before the engine is packed in the cover, it is fitted with moisture absorbing silica gel bags and moisture indicating silica gel boxes.

The engine packed in a polivinyl chloride cover is secured to shipping supports, which are bolted to the shipping case base; the case is fitted with a cover on top.

Enclosed inside the shipping case along with the engine are a set of spare parts for one engine, an aircraft-carried tools kit, and amplifier УРТ-19А-2Т.

Note: A tools kit is furnished with an engine having an even number.

The shipping case is sealed before being forwarded for delivery.

1. Prior to unpacking the engine, inspect the case externally to see that the seals are intact and that no damage has been done.

2. Remove the bolts fastening the case cover to the base.

3. Fasten the hoist slings to the four shackles on the case cover and lift the latter off the base.

4. Remove the polivinyl chloride cover from the engine in the following manner:

(a) cut the side seam of the cover and carefully roll the cover down;

(b) take the moisture absorbing silica gel bags, the moisture indicators, the paraffin paper, and the blanking covers off the engine.

Check the number of the silica gel bags against that specified in the accompanying papers.

5. Inspect the engine visually to see that there are no external defects; check engine completeness, the tools and the spare parts set enclosed, as well as the term of processing against the technical papers attached to the engine.

6. Perform external deprocessing of the engine, for which purpose use a brush soaked in clean gasoline to remove the processing compound from the engine parts and assemblies.

Carry out the job in a warm room.

Before starting the deprocessing procedure, warm up the engine to the outside air temperature.

In case no warm room is available, warm up the engine under the cover for 30 to 40 min. The temperature of heating air should not exceed 80°C.

[redacted]

7. Remove the blanking covers from the compressor intake and from the exhaust unit; use a cloth soaked with gasoline to rub the compressor intake, the inlet guide vane assembly, and the exhaust unit interior surfaces.

8. Check the HP-30 fuel regulating pump control lever for easy travel.

9. Rotate the low-pressure and high-pressure rotors manually; to rotate the low-pressure rotor, apply effort to the blades of the turbine 4th stage wheel; the high-pressure rotor must be spinned with the aid of special wrench 19-873 (provided in the tools kit, see Fig.54); it must be applied to the stand-by drive on the lower drive gear box. Both rotors should spin freely in the specified direction of rotation. The rotors must be rotated clockwise, if viewed from the exhaust unit end.

Note: It is allowed to keep an unpacked engine treated with anti-corrosion compound for storage in a heated room for three months (within the specified storage term).

2. INSTALLING ENGINE INSTRUMENT TRANSMITTERS (Fig.53)

The following transmitters must be installed on the engine for checking engine operating parameters:

(a) high-pressure rotor tachometer generator;
(b) low-pressure rotor tachometer generator;
(c) fuel pressure transmitter installed upstream of fuel regulating pump HP-30;
(d) primary fuel manifold pressure transmitter;
(e) engine inlet oil pressure transmitter;
(f) engine inlet oil temperature transmitter;
(g) vibration pickup MB-25B-B.

The vibration pickup must be installed on the by-pass duct entry housing from the side of engine attachment to the engine mount on the aircraft.

3. INSTALLING ENGINE ON AIRCRAFT

1. Slacken the bolts holding the engine to the case base.
2. Fasten the hoist slings and tighten the cable.
3. Screw off the nuts holding the engine to the supports.
4. Remove the engine from the support.
5. Remove the hangers fastening the engine to the case base and install them on the base.
6. Remove the nuts and protecting bushes from the brackets securing the engine to the mount on the aircraft.
7. Carefully lift up the engine and bring it to where it is to be installed; attach the hangers to the engine brackets, tighten up and lock the nuts fastening the hangers. Prior to mounting the engine, make sure to see that the engine final jet nozzle bevel corresponds to the nacelle bevel. Turn the final jet nozzle by 180 deg, if necessary.

CAUTION. (a) Hoist the engine with the aid of a crane not less than 2.5 tons in lifting capacity.
(b) Do not hoist the engine complete with the case base, making use of the engine hangers.

8. Check the engine position relative to the nacelle. If necessary, adjust the

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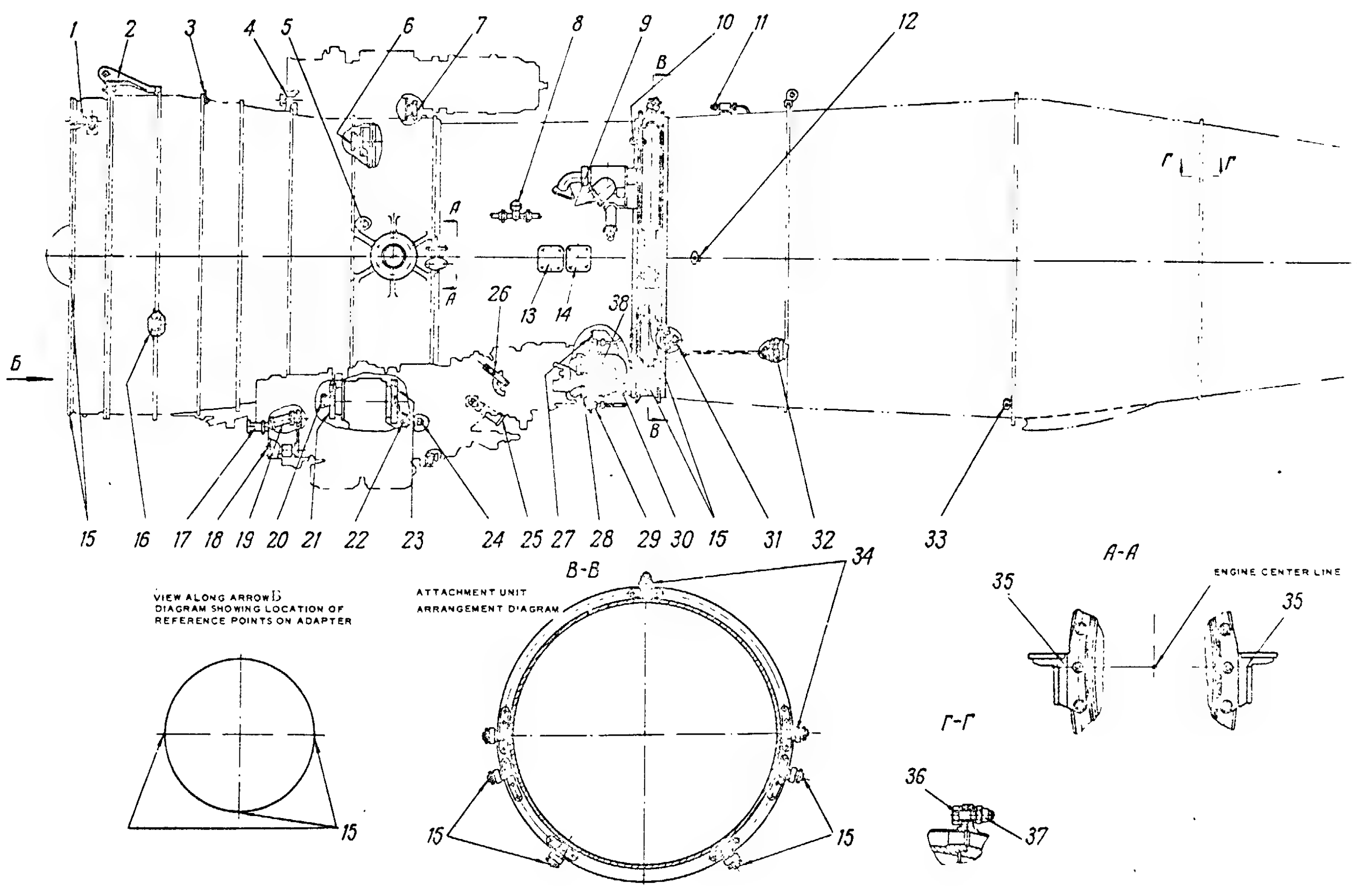

FIG. 53. ENGINE OPERATING PARAMETERS MEASUREMENT POINTS

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length of the engine mount rods. When installing the engine on the aircraft, take care that the engine and aircraft air intake ducts be flush within 2 mm upstream and within 3 mm downstream.

9. Connect the following to the engine:

(a) fuel and oil supply pipelines;

(b) air bleed pipelines supplying air to deicing systems and for pressurization of the hydraulic system tank.

CAUTION. When mounting the pipelines used for bleeding air for aircraft needs, take care to observe that their joints are tight enough;

(c) cables and wires:

- running to low-voltage wire harness plug connector;
- running to plug connectors of power sources, amplifiers, fire detectors and vibration pick-ups;
- running from measuring equipment transmitters to indicators;
- belonging to bonding system;
- running from block of Т-99-1 thermocouple manifold to overtemperature amplifier УРТ-19А-2Т and indicator ИТ-2 measuring outlet gas temperature;

(d) oil tank breathing pipeline;

(e) engine control lever link running to fuel regulating pump НР-30; adjust the engine control link;

(f) fire-fighting system pipelines.

The above stated connections of pipelines and wires to the engine and measuring equipment must be carried out in accordance with Fig.53.

10. Mount hydraulic pump НП43-1 (or НП43М-1) on the engine and connect the respective pipelines.

11. Install amplifier УРТ-19А-2Т attached to the engine and incorporated in overtemperature control system ПРТ-35. Connect wires to amplifier УРТ-19А-2Т installed in position.

4. DESCRIPTION OF MEASUREMENT POINTS REFERRED TO IN THIS CHAPTER AND SHOWN IN Fig.53

1. Engine oil outlet pipe connection.
2. Engine mounting bracket.
3. Bonding strip lugs, forward, 2 pcs.
4. Aircraft oil system tank breathing connection.
5. Pipe connection for bleeding air for pressurization of fuel tanks.
6. Drive to tachometer generator ДТЭ-5Т designed for measuring compressor low-pressure rotor rpm.
7. Drive to tachometer generator ДТЭ-5Т designed for measuring compressor high-pressure rotor rpm.
8. Pipe connection for extinguishant supply to fire-fighting system rings (2 points simmetrically located on the engine sides).
9. Flange for bleeding air aft of the 5th and 10th stages of compressor high-pressure section to supply it into the deicing system of the air intake.
10. Bonding strip lugs, aft, 2 pcs.

DESCRIPTION OF MEASUREMENTS POINTS

11. Pipe connection for extinguishant supply from the aircraft fire-fighting system to extinguish fire inside the engines.

12. Pipe connection for pressurizing the hydraulic tank.

13. Flange for bleeding air aft of the 4th stage of compressor high-pressure section for cabin pressurization. Air is bled via one flange only located either from the engine port or starboard side.

14. Flange for bleeding air aft of the 5th stage of the compressor high-pressure section for wing deicing system. Air is bled via one flange only either from the engine port or starboard side.

15. Datum points marked on the adapter external surface (on the air intake-to-engine attachment flange) – 3 points, and on the end faces of the engine mount brackets located on the hanger housing – 4 points.

16. Flange for installation of the toggle lever bracket in the engine control system.

17. Fuel outlet connection of booster pump [illegible].

18. Flange for fuel delivery to booster pump [illegible].

19. Connection for oil delivery to main oil pump [illegible]-30 from the aircraft oil tank.

20. Drive for manual cranking the compressor high-pressure rotor.

21. Stand-by drive.

22. Main pipe of piston pump [illegible]43-1 ([illegible]).

23. Drive to piston pump [illegible]43-1 ([illegible]).

24. Pad for installation of engine inlet oil temperature sensor П-63.

25. Fuel supply connection on fuel regulating pump HP-30.

26. Control lever of fuel regulating pump HP-30.

27. Pad for installation of transmitter [illegible]-4 (series III) with snubber [illegible]59-4, and pressure gauge [illegible]-4T (series III) for measuring fuel pressure at the inlet to fuel regulating pump HP-30.

28. Engine interval fire-fighting system plug connector:

[illegible] – plug.

[illegible] – receptacle (not supplied with the engine).

29. Pad for installation of transmitter [illegible]-8 (series III) with snubber [illegible]59-4 incorporated in engine induction-type indicator [illegible]-3[illegible] designed for measuring engine oil inlet pressure.

30. Low-voltage wire harness plug connector:

[illegible] – plug.

[illegible] – receptacle (not supplied with the engine).

31, 32. Pipe connections for anti-corrosion treatment of burner large-slot ducts. They are interconnected by hose 0539026 when processing the engine fuel system. The hose is available in the engine tools kit.

33. Wire lead-out block for a set of two T-99-1 thermocouple units. The wires run to indicator [illegible]-2 and amplifier [illegible].

34. Engine-to-aircraft attachment brackets, 7 pcs.

35. Brackets 30-00-044 (2 pcs) for attachment of engine vibration pick-ups.

36. Bolt 3150A-6-16 (passivated) – 75 pcs. (5 pcs are spare to be supplied additionally).

37. Nut 3373A-[illegible] – 76 pcs (20 spare nuts are additionally supplied).

[redacted]

38. Pad for installation of transmitter ИДТ-100 (series III) with snubber Д59-2 operating in set with engine indicator ЭМИ-3РТИ for measuring fuel pressure in the burner small-slot manifold.

5. INTERNAL DEPROCESSING OF ENGINE

Internal surfaces of the engine are deprocessed after the engine has been installed on the aircraft and all the lines have been connected.

Deprocessing is accomplished respectively by the use of fuel or oil in the following manner:

1. Drain oil from the engine.
2. Prepare the engine for starting as instructed in Chapter XI.
3. Motor the engine over and subject the high-pressure fuel system to pressure test, as recommended in Chapter XI.
4. Start the engine as instructed in Chapter XI, and run it at idle rpm for 5 min.
5. Shut down the engine.
6. After the first engine starting (deprocessing) do the following:

(a) perform the operations, referred to in Section "Post-Flight Servicing", Chapter III;

(b) discharge oil from the engine through the drain cock located in the lower drive gear box;

(c) remove, inspect and wash in clean gasoline or kerosene oil filter МФС-30 and the chip-detecting filter of centrifugal deaerator ЦВО-ФС-30;

(d) inspect the inlet and fine fuel filters incorporated in fuel regulating pump НР-30. Wash the filters, if necessary.

7. Run-up the engine as instructed in Chapter XI.
8. Prepare the engine for flight, as instructed in Chapter III.
9. Connect the air bleed pipelines to the engine to supply compressed air for pressurization of the aircraft cabins.

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RUN-UP OF NEWLY INSTALLED ENGINE

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Chapter XI

RUN-UP OF NEWLY INSTALLED ENGINE

1. PREPARATION OF NEWLY INSTALLED ENGINE FOR STARTING

Engine preparation for the first start on the aircraft consists in carrying out the following operations:

1. Perform operations set forth in Section "Preparation for Starting" of Chapter III.
2. Bleed air from the engine fuel supply system, using for that purpose the air bleed valves incorporated in fuel regulating pump НР-30 and centrifugal governor ЦР-1Б. To do this, remove dummy plugs from the valves, install a special appliance and release air until solid stream of fuel starts flowing out (about 10 lit).
3. Check the engine rotors for proper rotation. The rotors must rotate smoothly and without any jamming.
4. Motor the engine over.
5. Perform a "false" start of the engine.

2. ENGINE MOTORING OVER

The engine is motored over preparatory to starting in the following cases:

(a) when a new engine has been installed;
(b) if the engine lubricating oil system has been emptied of oil;
(c) after dismantling lubricating oil system units;
(d) after 2 or 3 aborted starts, if fuel failed to ignite;
(e) when the engine is inoperative for over 5 days.

To motor the engine over, proceed as follows:

1. Carry out all the operations prescribed for preparation of the engine for starting, for which purpose observe the instructions set forth in Section "Preparation of Engine for Starting" of Chapter III (see Item 1).

Make sure the engine control lever is set in the CUT-OFF position, the fuel booster pump is cut on, and the fuel shut-off valve is open.

2. Energize the electric instruments and automatic control system.
3. Cut in the master switch of automatic starting control unit АПД-19ЕД (series II).

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4. Set selector switch GROUND-AIR of automatic starting control unit АПД-19БД (series II) in the GROUND position.

5. Set the function switch of automatic starting control unit АПД-19БД (series II) in position ENGINE MOTORING OVER (ХОЛОДНАЯ ПРОКРУТКА ДВИГАТЕЛЯ).

6. Press the start button and keep it in the depressed position for 1 to 2 sec. As soon as the start button is depressed, the СТГ-12ТВМО starter-generators begin to spin the engine rotor. The starter-generators get disengaged automatically 30 to 36 sec later.

The engine speed during motoring over must be within 800 - 1200 rpm (7.0 - 10.0%).

7. Take care of engine inlet oil pressure that must be not less than 0.2 kg/sq.cm at a speed of from 800 to 1200 rpm (7.0 - 10.0%) during motoring over.

8. Upon completion of the engine motoring over, listen to the engine attentively in the course of run-down.

9. Stop the aircraft fuel pump and cut off the shut-off valve (after the compressor high-pressure rotor comes to a standstill).

Note: Do not accomplish the engine motoring over after inspecting the fuel filter of fuel regulating pump НР-30, the chip-detecting filter, the МФС-30 oil filter, after replacing scavenging oil pump МНО-30 and oil scavenge pipes.

3. ENGINE "FALSE" START

A "false" start of the engine is carried out for priming the fuel system and checking it for tightness. It should be done before the first start of a newly installed engine (during deprocessing of the engine), in case fuel system accessories or pipelines has been dismantled, or if the fuel system has been emptied of fuel.

A "false" start of the engine is performed as follows:

1. Deenergize the engine ignition system (for which purpose remove the safety fuse or uncouple the plug connector in the power supply line of ignition unit СКНА-22-2А).

2. Switch on the power supply to the instrument and the automatic control system equipment.

3. Cut in the master switch of automatic starting control unit АПД-19БД (series II).

4. Set selector switch GROUND-AIR of automatic starting control unit АПД-19БД (series II) in position GROUND.

5. Set the function switch of automatic starting control unit АПД-19БД (series II) in position START.

6. Prepare the engine control lever for setting it in the IDLE position.

7. Open the engine shut-off valve and cut on the aircraft fuel booster pump.

8. Press the START button and keep it depressed for 1 to 2 sec.

The time of engine rotation in the course of the "false" start is determined by the operation of automatic starting control unit АПД-19БД (series II) to be within 45 - 50 sec. At a speed of from 800 to 1000 rpm (7 - 8.5%) set the engine control lever to the IDLE position. As soon as fuel pressure rises in the fuel manifold and fuel mist is seen coming out of the exhaust nozzle, inspect the fuel system units for leaks and cut off the fuel supply into the engine by retarding the engine control lever to the CUT-OFF position.

The engine control lever must be moved to the CUT-OFF position not later than 35 sec after the beginning of the starting procedure, which makes it possible to blow out fuel accumulated in the engine flow path.

Maximum rotor speed during "false" starts is within 1800 - 2300 rpm (15.5 - 20.0%).

9. When the engine is steadily motored over, the engine inlet oil pressure must be not less than 0.5 kg/sq.cm and fuel pressure in the primary fuel manifold should be within 10 - 20 kg/sq.cm.

10. After the starter-generators are disengaged and the engine rotors decelerate rotating by inertia, listen to the engine attentively to detect foreign noise inside the engine.

11. Cut off the aircraft fuel booster pump and close the fuel shut-off valve (after the compressor high-pressure rotor comes to a standstill).

12. Inspect the connections of the pipelines and units of the fuel supply and lubricating oil systems. Leaks of fuel or oil are not permissible.

13. Drain oil from the lower drive gear box.

<u>Notes:</u> (a) If no oil pressure is registered at the engine inlet during motoring over or "false" start of a newly installed engine, unscrew the plug from the housing of main oil pump ОМН-30 and bleed air from the pipeline supplying oil from the tank into the engine;
(b) In case it is required to perform the engine motoring over and a "false" start, it is allowed to carry out a "false" start only.

4. STARTING, WARMING-UP, TRIAL AND SHUT-DOWN OF ENGINE

To start, warm-up, try out and shut down of a newly installed engine, follow the respective procedures described in Chapter III.

CAUTION. After starting of a newly installed engine, run the engine for 5 min at idle rpm before warming it up, then shut the engine down and inspect its fuel and oil lines and units for leaks.

5. MAINTENANCE OPERATIONS TO BE CARRIED OUT AFTER TRIAL OF NEWLY INSTALLED ENGINE

1. When the engine fuel supply system is cut off and its rotors run-down by inertia, listen to the engine attentively to make sure there is no foreign noise within the engine and measure the run-down time of the low-pressure and high-pressure rotors, as instructed in Section 5 of Chapter III.

2. After the engine rotors are at a standstill, open the aircraft shutters and access doors.

3. Ascertain that there is no leakage of fuel or oil. Eliminate leaky connections, if any detected.

4. Drain oil from the lower drive gear box of the engine.

5. Examine oil filter МФС-30 and the chip-detecting filter of centrifugal deaerator ЦВО-ФС-30. Wash the filters in clean gasoline or kerosene, if needed. Make use of a tester to check the chip-detecting filter discs for short-circuiting.

In case the short circuit of the chip-detecting filter discs is not eliminated by rinsing the filter in gasoline or kerosene, strip the chip-detecting filter and wash the discs separately. Pay attention to the condition of the disc insulating lugs. Replace damaged discs.

6. Inspect the inlet filter and fine fuel filter of fuel regulating pump HP-30 and the fine fuel filter of centrifugal governor UP-2B. Wash the filters in clean gasoline or kerosene, if necessary. The inspection over, bleed air from fuel regulating pump HP-30 and centrifugal governor UP-1B.

Notes: (a) If chips are detected in the oil system filters, consult the representative of the Manufacturing plant as to further use of the engine;

(b) If fuel has been drained from the fuel system for some reason or other, it is imperative to subject the system to anti-corrosion treatment within 24 hours as instructed in Chapter XII.

7. Check the oil level in the oil tank. Add oil, if required.

8. Inspect the engine inlet duct, the inlet guide vanes, observable blades of the compressor first spool, the nozzle diaphragm and moving blades of the turbine fourth stage. Inspect the jet nozzle. No damage is allowed.

9. Inspect fastening and locking of all the attachment units, of the engine, accessories and pipelines.

10. The inspection over, close the engine inlet duct and exhaust nozzle with dummy covers. The jet nozzle dummy cover must be installed 10 or 15 minutes after the engine has come to a standstill.

6. OPERATIONS TO BE PERFORMED AFTER MAIDEN FLIGHT OF NEWLY INSTALLED ENGINE

After the maiden flight of a newly installed engine carry out operations prescribed in Section 5 "Maintenance Operations to be Carried Out After Trial of Newly Installed Engine". As an exception, do not inspect the inlet filter of fuel regulating pump HP-30, when carrying out operations according to Item 6.

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PROCESSING OF ENGINE AND UNITS AND REMOVAL OF ENGINE FROM AIRCRAFT

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Chapter XII

PROCESSING OF ENGINE AND UNITS AND REMOVAL OF ENGINE FROM AIRCRAFT

Engine processing is the principal method of protecting the engine components against corrosion both during storage and shipment.

Protection against corrosion is accomplished by applying a layer of appropriate processing compounds on the internal and external surfaces of the engine parts and assemblies.

Internal processing is done by the use of oil МК-8 (USSR Standard GOST 6457-53) and oil МК-8П (Specification МРТУ 12Н No.12-62).

External processing should be performed with the aid of gun grease (USSR Standard GOST 3005-51) or neutral petrolatum (USSR Standard GOST 782-47).

Reclaimed or used oils and greases are not to be used for engine processing.

Notes: (a) In case oil ВНИИ НП-50-1-4Ф was used in the engine, it is necessary to drain this oil from the engine and aircraft lubricating oil systems, if the latter are to be processed with oils МК-8 or МК-8П. Then the systems must be filled with oil МК-8 or МК8П, the engine should be motored over and started.

Before processing the engine oil system, run the engine at idle speed for 5 minutes, then at 0.7 normal rating for 2 or 5 minutes. Afterwards drain oil from the aircraft and engine lubricating oil systems and subject the engine to anti-corrosion treatment;

(b) In service intervals it is allowed to process the engine and its units with oil ВНИИ НП-50-1-4Ф, if the engine and its units are not to be removed and forwarded to the Manufacturing plant.

1. PROCESSING OF ENGINE ON AIRCRAFT

In case an interval in engine operation on the aircraft amounts to less than 10 days, no special processing is required, since the fuel system passages are protected against corrosion by the fuel trapped. If fuel has been drained from the fuel system units, it is necessary (within not more than 24 hours) to fill the fuel system with fuel, bleed air from centrifugal governor ЦР-1В and from fuel regulating pump НР-30, then perform a "false" start of the engine. If the fuel system cannot be filled with fuel, process the engine by the use of oil, as instructed below.

If the interval in engine operation amounts up to 30 days, carry out "false" starts of the engine every 10 or 15 days as instructed in Chapter XI.

Whenever up to 30 days elapse since the engine has been last operated on the aircraft and the aircraft is to be out of service for a long period of time, one internal processing may be performed instead of engine false starts previously advis-

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ed. Internal processing of the engine will provide protection against corrosion within 30 days. In the event the engine remains inoperative for more than 30 days, internal processing should be done once every 30 days.

Note: In case the engine has been stored for a long period (exceeding 3 months), deprocess the engine as instructed in Chapter X of this Book, run the engine idle for 2 minutes and at 0.7 normal rating for 2 or 5 minutes, after which deprocess the engine, if it is to be kept inoperative.

Before performing internal processing of the engine, start the engine and run it for 2 min at idle rpm and for 2 to 5 min at 0.7 normal rating.

Note: In exceptional cases, when the engine cannot be started, interval processing may be accomplished without engine starting and warming up.

Internal processing is performed after the engine cools down, to prevent oil burning.

Internal processing is to be carried out in the following manner:

1. Fill the cleaned tank of the processing rig with clean oil МК-8 or МК-8П or with oil ВНИИ НП-50-1-4Ф, preheated to 50 - 60°C; the tank should hold 20 to 24 lit of oil.

2. Close the fuel system shut-off valve.

3. Connect the hose of the processing rig tank to the processing union disposed on the fuel line upstream of fuel regulating pump НР-30.

4. Remove the caps from the union of the pipe serving for measuring pressure in the primary fuel manifold and from the main fuel manifold union. Fit hose 0889026 for processing the fuel manifolds onto the open unions.

Remove the caps from the air bleed union located on centrifugal governor ЦР-1Б and fuel regulating pump НР-30, then connect appliance 19-811 serving for air bleeding.

5. Energize the instruments and automatic control system of the engine.

6. Build up an oil pressure of 1.8 to 2.9 kg/sq.cm at the inlet to fuel regulating pump НР-30, making use of the processing rig, and drain fuel through the air bleed valve from fuel regulating pump НР-30 and from centrifugal governor ЦР-1Б until a stream of clean oil shows up, after which discontinue oil delivery from the processing rig.

7. Perform a "false" start of the engine as instructed in Chapter XI. The engine shut-off valve must be kept closed. The booster pump of the processing rig should be cut in beforehand.

While the engine is being cranked, shift the engine control lever from the CUT-OFF position to a position corresponding to one of the engine operating ratings. This should cause oil pressure to be increased upstream of the burners up to 10 or 20 kg/sq.cm. Shift the engine control lever to the CUT-OFF position as soon as oil must flows out of the engine jet nozzle.

8. After the engine rotor comes to a standstill cut out the processing rig pumps, the power supply to the engine instruments and automatic control system, remove hose 0889026 for processing the main and primary fuel manifolds, fit the unions with caps and lock the latter.

9. Remove the air bleeding appliance from units НР-30 and ЦР-1Б, fit the unions with caps and apply the locks.

10. Fit blanking covers into the engine air intake and into the exhaust unit.

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CAUTION. Do not subject the engine to anti-corrosion treatment in rain or snowfall.

2. PROCESSING OF ACCESSORY UNITS REMOVED FROM ENGINE

In case a non-processed engine is dismantled from the aircraft, it is necessary to perform internal processing of aircraft fuel booster pump ДЦН-44-ПЗТ without dismantling it from the engine, then remove fuel regulating pump HP-30, centrifugal governors ЦР-1В and ЦР-2В and fuel burners ФР-30ДС and subject them to anti-corrosion treatment not later than 24 hours after draining fuel, as instructed below.

(a) Processing of Fuel Regulating Pump HP-30

Fuel regulating pump HP-30 dismantled from the engine is to be processed within 24 hours.

1. For internal processing of the fuel regulating pump use should be made of clean corrosion-preventive oils preheated to a temperature of 50 to 60°C.

All cavities of the fuel regulating pump are subject to processing, except the air chamber of the starting fuel control unit and solenoid plug connector of the overtemperature limiter.

Prior to performing the processing procedure do the following: drain fuel from the pump, remove and wash the inlet and fine fuel filters, close all the holes, except the union serving for conveying fuel to centrifugal governor ЦР-2В, with shipping caps.

Deliver oil at a pressure of 1 to 1.5 kg/sq.cm through the fuel inlet connection. Meanwhile do the following:

(a) bleed air and fuel from the pump via the air bleed valve;

(b) keep turning the pump rotor by the shank of the coupling shaft moving the engine control lever from the CUT-OFF to TAKE-OFF position and back several times until about 0.8 to 1.0 lit of oil runs out of the union serving for fuel supply to centrifugal governor ЦР-2В.

Stop the union for conveying fuel to centrifugal governor ЦР-2В.

Remove the shipping caps from the unions serving for fuel delivery to the primary and main fuel manifolds, as well as from the drain valve union.

Supply oil at a pressure of 1 to 1.5 kg/sq.cm through the primary fuel manifold union.

Keep turning the pump rotor by the coupling shaft shank, until about 0.8 to 1.0 lit of oil runs out of the main fuel manifold union and from the drain valve union.

After internal processing is completed, drain excess oil from the pump via the fuel supply connection.

2. External processing of fuel regulating pump HP-30 is performed with the aid of gun grease (State Standard GOST 3005-51) or petrolatum (State Standard GOST 782-47), preheated to a temperature of 60 - 80°C.

Subject to external processing are all the outer surfaces having no paint coating, except the plug connector and electromagnet of the overtemperature limiter.

Areas to be processed must be washed with clean gasoline before the processing compound is applied.

(b) Processing of Centrifugal Governors ЦР-1Б and ЦР-2Б

1. Centrifugal governors ЦР-1Б and ЦР-2Б must be processed within 24 hours after being dismantled from the engine.

Internal surfaces of the units are processed with the aid of above mentioned oils preheated to a temperature of 50 to 60°C. Subject to processing are all the internal cavities and components of the centrifugal governors, exclusive of the electric switches and the plug connector of centrifugal governor ЦР-2Б.

Prior to processing the internal surfaces, drain fuel from the centrifugal governors.

Processing oil is delivered at a pressure of 1.0 to 1.5 kg/sq.cm into centrifugal governor ЦР-1Б via the unions serving for the supply of fuel from the hydraulic decelerator of fuel regulating pump НР-30 and through the union serving for draining fuel from centrifugal governor ЦР-1Б. While delivering the oil, keep rotating the centrifugal governor by the shank of the coupling shaft, until oil starts flowing from the union through which fuel is supplied from centrifugal governor ЦР-2Б. Do not fail to bleed air and fuel from the governor via the air bleed valve until oil starts flowing out.

In the case of centrifugal governor ЦР-2Б processing oil is supplied at a pressure of 1.0 to 1.5 kg/sq.cm through the union serving for fuel drain and via the union used for high-pressure fuel supply from the hydraulic decelerator incorporated in fuel regulating pump НР-30.

2. For external processing of centrifugal governors ЦР-1Б and ЦР-2Б, use should be made of gun grease (St. Std GOST 3005-51) or petrolatum (St. Std GOST 782-47), heated to a temperature of 60 to 70°C.

Subject to external processing are all the outside surfaces having no paint coating, except the microswitch box and the plug connector of centrifugal governor ЦР-2Б.

Before applying processing oil, wash the areas to be processed with clean gasoline or kerosene.

(c) Processing of Main Burners ФР-30БС

The main burners should be processed within 24 hours after being removed from the engine.

Prior to applying the processing compound, flush the internal passages of the burners with clean gasoline Б-70 at a pressure of 2 to 3 kg/sq.cm. Flush the burners with hot engine processing oil heated to a temperature of 50 to 60°C and delivered at a pressure of 1.5 to 2 kg/sq.cm, until the oil starts running from the burner nozzles.

After the flushing procedure is completed, coat the burner nozzle face with neutral gun grease flush with the casing, after which put the protective caps on the nozzles and pipe connections. Coat the burner external surface with petrolatum or neutral gun grease heated to a temperature of 60 to 80°C.

Note: It is allowed to subject the main burners to anti-corrosion treatment without dismantling them from the engine. To process the burners in this case, disconnect the pipelines supplying fuel into the primary and main fuel manifolds and connect the processing rig hoses instead.

Pump 1 to 1.5 lit of oil through the burners at a pressure of 1.5 to 2.0 kg/sq.cm having preheated the oil to a temperature of 50 to 60°C.

The storage term for the main burners thus processed should not exceed 1 month.

3. PROCESSING OF ENGINE FOR DISMANTLING IT FROM AIRCRAFT

Whenever the engine is removed from the aircraft, it is subject to processing for a term of 3 months.

Prior to dismantling the engine, it must be subjected to internal processing, as instructed in the Section above.

While performing internal processing of the engine, process hydraulic pump НП43-1 (НП43М-1) for which purpose detach the inlet and outlet pipes from the pump and fit the respective unions with hoses. Lower the inlet hose into a container with oil МК-8 or МК-8П; lower the outlet hose into an empty container.

When cranking the engine, place the container with the processing oil not less than one metre above the pump inlet. After engine cranking is completed (during internal processing of the engine) ascertain that not less than 3 lit of oil have been run through the pump.

Having completed engine processing on the aircraft, disconnect the fuel and oil supply pipes from the engine; remove the instrument transmitters, detach the air bleed pipes and fit the respective holes with plugs. Do not use paper or wooden plugs. Disconnect the electric system wiring. Remove the engine from the aircraft.

After removing the engine from the aircraft, proceed as follows:

1. Prime 1.5 or 2 lit of oil heated to a temperature of 50 to 60°C through booster pump ЭЦН-44-ПОТ. Make use of the pump outlet pipe connection for that purpose.

In doing this, rotate the engine high-pressure rotor by means of the stand-by drive shaft.

2. Check to see that all the openings on the engine are pluged; install plugs, if any missing.

3. Clean the external surfaces of the engine of dust and oil, making use of cloth soaked in gasoline Б-70. Prevent gasoline from getting onto electric wiring, electric system units, rubber parts, thermal insulation of pipelines and units. Dry out the cleaned surfaces.

4. Coat all the non-painted external surfaces of the engine components with a layer of gun grease or neutral petrolatum. Prior to applying the processing compound, heat it to a temperature of 60 to 80°C.

<u>Notes</u>: (a) Do not process the components manufactured from stainless alloys;
(b) process the external surfaces of the engine not later than 72 hours after performing internal processing;
(c) all the engine processing operations should be performed in close succession.

4. PACKING OF ENGINE

1. Check to see that the unions and holes leading inside the engine are fitted with caps and plugs.

2. Check to see that each of the engine accessory units is provided with its service log or certificate.

3. Ascertain that the engine accessories are fitted with seals.

4. After completing the engine processing procedure, mount the engine onto the base of the packing case and fasten it thereon.

5. Rub the electric units, and the electric equipment components (such as ignition plugs, plug connectors, electric system conduits, etc.) with a dry cloth and wrap them in paraffin paper. Do not remove the ignition plugs from the engine.

6. Put a vinyl chloride cover onto the engine and pack the engine in a dry wooden case. Secure the case cover to the base with the aid of clamping bolts. Apply a seal to the case-to-base joint.

<u>Notes</u>: (a) When transported by air, the engine is mounted on a special support. In this case the engine packing procedure is the same as when packing the engine in a case;
(b) Prior to packing the engine into a case do not fail to attach all the removed accessory units and overtemperature amplifier УРТ-19А-2Т.

AIRBORNE TOOLS USED FOR ENGINE SERVICING

Chapter XIII

AIRBORNE TOOLS USED FOR ENGINE SERVICING

Engine servicing is accomplished with the aid of the following tools and appliances, contained in the tools kit (see Fig.54) attached to engines bearing even numbers.

Drawing No.	Name of tool or appliance	Q-ty	Application
19-801	Hammer	1	Used for hammering operations
702258	Screw driver, medium size	1	General purpose
702176	Screw driver, large size	1	General purpose
19-805	Wrench rod, hinged	1	Used for wrench detachable heads complete with bar 19-886
14-19-843	Torque wrench	1	Used with detachable wrench heads
18-19-833	Appliance	1	For bleeding air from fuel system
19-820	Brush	1	For washing filters
702039	Knife	1	General purpose
19-824	Socket wrench head, S = 14 mm	1	General purpose
14-19-003	Screw driver	1	General purpose
18-19-010	Open end wrench, S = 7x7 mm	1	For bolts securing fuel burners
18-19-008	Wrench	1	For attachment of pipeline connection delivering oil into lower drive gear box
19-836	Socket wrench head, S = 17 mm	1	General purpose
19-873	Cranking bar	1	For spinning engine rotor
19-874	Forceps	1	For handling fuel filters enclosed in fuel system units
19-886	Bar	1	To be used with hinged wrench rod 19-805
19-908	Socket wrench head, S = 12 mm	1	General purpose
19-915	Torque wrench rated for 0.04 to 0.37 kgm		For tightening thermocouple attachment nuts

Drawing No.	Name of tool or appliance	Q-ty	Application
200 USSR St. Std 5547-52	Electritian's pliers	1	General purpose
19.916	Socket wrench head, S = 10 mm	1	For tightening thermocouple attachment bolts
19-917	Socket wrench head, S = 8 mm	1	For tightening nuts holding wire lugs to thermocouples
702260	Screw driver, special medium size	1	For plug connector screws
0889026	Hose	1	For processing engine fuel system
19-922	Puller	1	For hydraulic decelerator and other flow restrictors
19-924	Socket wrench head, S = 7 mm	1	For tightening nuts holding wire lugs to thermocouples
19-925	Wrench, S = 17 mm	1	For attachment of pipeline to fuel burner
19-926	Appliance	1	For washing oil filter elements
19-933	Rod	1	To be used with torque wrench and wrench detachable heads
19-011	Rod	1	To be used with hinged wrench rod 19-805 intended for detachable heads
19-012	Chisel	1	For unbending tabs of plate locks
19-018	Tommy bar	1	To be used with wrenches
19-019	Drift	1	Used for knocking out
19-073	Box wrench, S = 14x17	1	General purpose
19-945	Open end wrench	1	For chip-detecting filter nut
19-946	Arbour	1	For holding chip-detecting filter core
14-19-043	Socket wrench head, S = 19 mm	1	General purpose
703383	Open end wrench, S = 10x12	2	General purpose
19-086	Open end wrench, S = 14x17	2	General purpose
19-087	Open end wrench, S = 19x22	2	General purpose
19-088	Open end wrench, S = 22x27	2	General purpose
19-089	Open end wrench, S = 30x32	1	General purpose
19-090	Open end wrench, S = 36x41	1	General purpose
19-091	Open end wrench, S = 46x50	1	General purpose
18-19-011	Open end wrench, S = 4x4 mm and S = 5x5 mm	1	For fuel system unit adjusting screws, main oil pump pressure control valve adjusting screw, and hydraulic decelerator adjusting screw incorporat-

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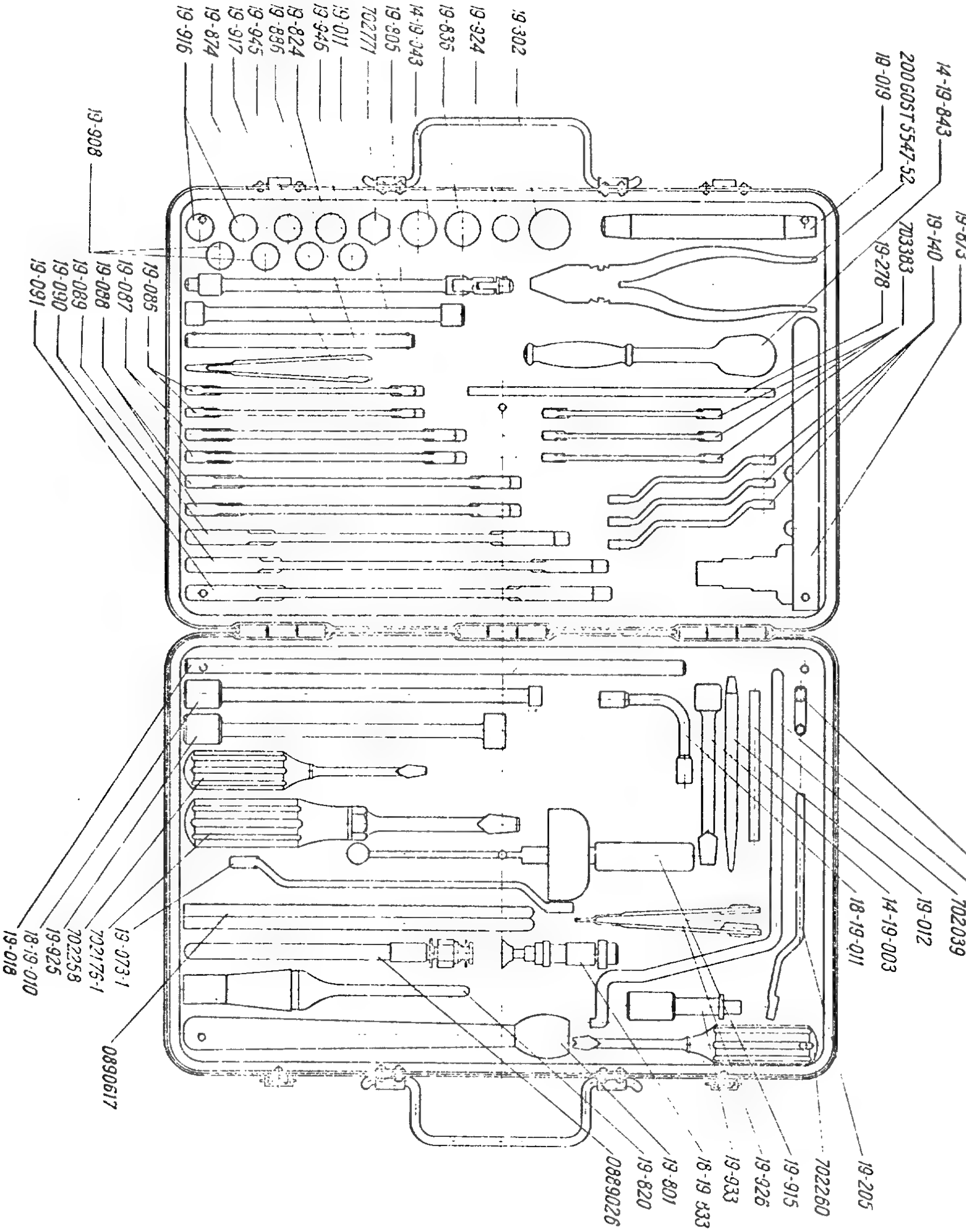

FIG. 54. AIRBORNE TO... KIT

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Drawing No.	Name of tool or appliance	Qn-ty	Application
			ed in fuel regulating pump HP-30
702771	Socket wrench head, S = 22 mm	1	For removing filter from fuel connection at inlet to fuel regulating pump HP-30
19-278	Open end wrench	1	For attachment of breathing pipeline and tachometer generator
19-140	Box wrench, S = 10x12 mm	1	General purpose
19-205	Open end wrench, S = 12 mm	1	For nuts attaching upper drive gear box
19-302	Socket wrench head, S = 22 mm	1	For magnetic plug incorporated in lower drive gear box
Without drawing	Safety wire KC-1, USSR St. Std GOST 792-41	as required	
0890617	Rubber tube	1	To be used with appliance 19-811 for bleeding air

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HEAT-RESISTING COMPOUND "XC"

HEAT-RESISTING COMPOUND "ЖС"

(Instructions on preparation and application)

1. PURPOSE

Lubricant compound "ЖС" prevents sticking of threaded connections operating at temperatures of up to 600 - 800°C.

The lubricant has been checked in laboratory and service conditions and yielded good results. Patent No.128093 was granted for the compound in 1960.

2. PREPARATION OF COMPOUND "ЖС"

(a) Preparation of Lead Carbonate

Weigh a batch of litharge and dissolve it in nitric acid of specific gravity 1.2. Litharge must be taken in proportion 1 kg per 1.2 to 1.5 lit of nitric acid. Litharge should be dissolved in a stainless steel vessel that must be heated. Pour litharge gradually, stirring the solution continuously, then add 3 or 4 lit of hot water. Filter the vessel content through filtering paper to remove hard admixtures.

To avoid intensive frothing, add filtered soda ash solution (0.4 - 0.5 kg per 2 - 3 lit) into the lead nitrate solution previously obtained in small quantities, until the solution is rose-coloured when tested with phenolphtalein. Lead carbonate separates out in the form of white sediment.

(b) Washing

Let the lead carbonate settle, siphon off the water solution, decant the residue by water until the decanted water is neutral when tested with phenolphtalein. Afterwards, filter the residue through a Buchner funnel with filtering paper, drawing off the sediment by means of a water-jet pump.

(c) Drying-Up

Spread the separated lead carbonate in a layer 10 to 15 mm thick over pans made of stainless steel (which must be covered by filtering paper beforehand) or over porcelain dishes. Keep the lead carbonate for 14 to 16 hours at a temperature of 110 to 120°C to dry it up.

(d) Preparation of Compound

Grind sifted lead carbonate in a porcelain mortar adding cylinder oil, Grade 52 (Vapour), conforming to St. Std GOST 6411-52, until a homogeneous stuff is obtained. Oil should be added in small portions, observing the required proportion of 1 kg of oil per 1.5 kg of lead carbonate.

3. APPLICATION HINTS

Prior to installing a bolt in position, dip its threaded end into the compound as deep as 3 or 4 thread turns. Shake off excess lubricant into a can. The female thread is not necessarily coated with the compound in this case. When it is desired to screw down a nut on a stud, make use of a brush to apply some compound on 2 or 3 starting threads of the stud.

SILICONE ENAMEL

SILICONE ENAMEL

(Instructions on preparation and application)

1. APPLICATION

The silicone enamel is of silvery colour and is designed for sealing joint faces.

2. PREPARATION

The ingredients of the silicone enamel are:

(a) varnish ФГ-9, Technical Standard (МХПТУ) 2273-53 - 70 to 84%;

(b) siccative No.7640, Technical Standard (МХПТУ) 2106-49 - 10%;

(c) aluminium powder, State Standard (ГОСТ) 5494-50 - 6 to 20%;

(d) varnish K-1, State Standard (ВТУ) No.ЕУ-168-58 - 0 to 50% in relation to varnish ФГ-9.

When varnish K-1 is used, siccative No.7640 is substituted for by a corresponding amount of mixture composed of varnishes ФГ-9 and K-1.

Tó prepare the enamel, proceed as follows.

Thoroughly mix up varnishes ФГ-9 and K-1 and filter the mixture through a gauze folded in two. Add part of varnish batch by small portions into aluminium powder batch, then after the powder gets wetted with varnish, thoroughly grind the obtained mass in a porcelain mortar. Carry out grinding for at least half a hour, after which add the remaining portion of varnish ФГ-9 and the siccative to the paste obtained (no siccative is to be added if a mixture of varnishes ФГ-9 and K-1 is used); when adding, mix the paste continuously. Take care to see that proper exhaust ventilation is provided for during the preparation procedure. After the enamel is prepared, check it for viscosity. The viscosity measured by model ВЗ-1 viscosimeter should be equal to 2 - 7 sec, while that shown by model ВЗ-4 viscosimeter is within 10 to 30 sec.

The silicone enamel is intended for use during a period of 5 days.

3. TECHNOLOGICAL TEST

Technological test is carried out in case all the enamel components, or one of them (varnishes ФГ-9 and K-1, aluminium powder, siccative) have been substituted for. The test is performed as follows.

Apply a thin uniform layer of the tested enamel to an aluminium plate by means of a brush. After the layer gets dry so that it may come off (in 4 - 10 minutes), coat it with another layer of enamel.

When this layer gets also dry so that it may come off (in 5 - 15 minutes), cover it with tracing paper and smooth the paper thoroughly to the plate. The wet spots left on the tracing paper should not occupy more than 50 - 60% of the entire surface.

The silicone enamel is considered fit for use if the technological test results are satisfactory.

4. STORAGE

The prepared enamel is to be stored in a jar with a lapped-in plug, or in a special can. The packing must be provided with the Manufacturer's Certificate.

Before using the enamel, stir it up thoroughly in the can and then pour it into a service can provided with a tightly sealed cover.

Use a brush or a sprayer to apply the enamel to the working surface.

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